THE JOURNAL
OF THE
ROYAL AERONAUTICAL SOCIETY

(FOUNDED 1897 in succession to the ANNUAL REPORTS)

Edited for the Council by J. LAURENCE PRITCHARD, Fellow

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NOTICES

Donations

The Council gratefully acknowledge donations of £250 from Sir Charles Wakefield and of £100 from "A Friend of Aviation" to the Endowment Fund of the Society. Lord Cowdray has most generously promised to give £50 a year to the Society for five years if nine other people will do the same.

One Member whose subscription has been reduced has given the balance to the Library Fund. It is hoped that other Members will follow his example.

Formation of Branches

On pages 77-78 is printed a résumé of the new rules in connection with the formation of branches of the Society.

The first branch to be formed is at Coventry, under the direction of Mr. J. D. Siddeley and Major F. M. Green, both Fellows of the Society. The Coventry Branch of the Royal Aeronautical Society has already over 100 members. Its Hon. Secretary is F. Meadows. Other branches of the Society are in the course of formation, and notices of their activities will appear from time to time in the Journal.

Associateship

On page 77 are printed extracts from the rules dealing with the new technical grade of Associateship. Forms of application for membership for the new grade are now ready.

Alteration of the Time of Lectures

Members are particularly requested to note the change of time for the Society's lectures from 5.30 p.m. to 6.30 p.m.

Library

The Council acknowledge gratefully a presentation copy of "E. T. Busk" from Mrs. Busk, and of "The German Air Raids in Great Britain, 1914-1918," by Captain J. Morris, A.F.R.Ae.S.

The following Reports and Memoranda of the Aeronautical Research Committee have been received for the Library:—No. 967, "An Experimental Study of the Vibration in the Blades and Shaft of an Airscrew," by A. Fage; No. 973, "The Lateral Control of a Biplane by Combined Use of Ailerons and Varying Leading Edge Slots," by G. P. Douglas, F. B. Bradfield and A. S. Hartshorn; No. 974, "Report on the Use of Artificial Sources of Light as a Substitute in the Weathering of Fabric: Part I.," by W. G. Glendinning; and No. 980, "The Rolling and Yawing Moments of an Aerofoil in Straight Flight," by H. Glauert.

Visits

All members of the Society in whatever grade may join the party of Students visiting the London Terminal Aerodrome on Saturday afternoon, February 6th, and the de Havilland Aircraft Company's Works on Saturday morning, February 27th. They are, however, asked to send in their names to the Secretary beforehand in order that some idea of the size of the party may be known.

Students' Section Programme

Saturday, February 6th.—Visit to Croydon Aerodrome. Meet at Trust House Hotel Entrance at 3.0 p.m. sharp. Captain H. R. Gillman, Associate Fellow, will conduct the party round.

Thursday, February 18th, 6.0 p.m.—In the Library. Lecture and Discussion "Bernoulli and Aerodynamics," Mr. M. S. Hooper.

Saturday, February 27th.—Visit to the de Havilland Aircraft Company's Works at Stag Lane Aerodrome. Meet at Burnt Oak Tube Station at 10 a.m.

Thursday, March 11th, 6.0 p.m.—In the Library. "Experimental Flying from the Pilot's Point of View," by F./O. R. L. Ragg.

Thursday, March 25th, 6.0 p.m.—In the Library. Lecture and Discussion "Stalled Flying," by Mr. S. S. Hall, B.Sc., D.S.C.

Thursday, April 8th, 6.0 p.m.—In the Library. Lecture (to be announced later).

Further visits to be arranged for May and June.

Will those Students who wish to take part in any visit kindly let the Secretary know as early as possible, so that the necessary arrangements can be made?

The Month's Arrangements

February 4th, 7.0 p.m.—Joint Meeting with the Institution of Automobile Engineers, at the Royal Society of Arts, 18, John Street, Adelphi, W.C.2. "American Aircraft Engine Development," by Mr. C. L. Lawrance. Light Refreshments at 6.30 p.m.

February 6th.—Students' Visit to Croydon Aerodrome. Meet at Trust House Hotel Entrance at 3.0 p.m. sharp. Captain H. R. Gillman, A.F.R.Ae.S., will conduct the party round. Members wishing to join the party are asked to send in their names early.

February 16th, 5.30 p.m.—Council Meeting in the Library.

February 18th, 6.0 p.m.—In the Library. Students' Meeting. Lecture and Discussion, "Bernoulli and Aerodynamics," by Mr. M. S. Hooper.

February 18th, *Glasgow Branch*.—"Air Preparedness: the Relative Positions of the Nations in the Air To-day," by Mr. C. G. Grey.

February 25th, 6.30 p.m.—In the Library. "Long Distance Aeroplane Flights," by Mr. A. J. Cobham.

February 27th.—Students' Visit to the de Havilland Aircraft Company's Works. Meet at Burnt Oak Tube Station at 10 a.m. sharp.

J. LAURENCE PRITCHARD, *Hon. Secretary*

ASSOCIATESHIP

At a special General Meeting held on December 30th, 1925, it was decided to form a new technical grade. Persons belonging to this grade will be called ASSOCIATES, will receive a Certificate of Associateship, and will have the right to place the letters A.R.Ae.S. after their names. The following is a brief résumé of the rules dealing with the new grade:

Associates.—Persons employed in a technical capacity in the manufacture or operation of aircraft, and who are duly qualified in accordance with the regulations for the time being in force.

Examples of the type of qualifications required:

(*a*) A ground engineer's certificate in at least two categories.

(*b*) Having held a position for at least two years as inspector and examiner of aeronautical materials.

(*c*) A pilot's "B" licence.

(*d*) A navigator's certificate.

(*e*) A commissioned or warrant rank in the general duties branch of the R.A.F.

(*f*) Having held a position equivalent to that of foreman for a period of not less than three years.

In the absence of any of these qualifications the candidate may be required to produce evidence of his suitability for this grade, and each application for election will be considered on its merits by the Council.

Ladies shall be eligible for the above grade.

Privileges.—All members of the Society, in whatever grades, are entitled to attend at all meetings of the Society and take part in all discussions.

Introduce guests to the Society's meetings and discussions other than those of a business character.

Use the Society's Library, subject to the regulations for the time being in force.

Associates are also entitled to a certificate of Associateship and for the purpose of designating their technical status to use the abbreviation A.R.Ae.S.

Associates are entitled to full voting powers.

Annual Subscription if Journal is required	...	£2 2 0
Annual Subscription if Journal is not required	...	£1 1 0

The Council have under consideration the question of proposing an entrance fee for Associates joining after December 31st, 1926.

Persons desiring to become Associates must be proposed and seconded by Fellows or Associate Fellows of the Society. Application forms and any further information may be obtained on application to the Hon. Secretary.

The Council have under consideration the issue of technical information, probably in the form of data sheets, suitable for those members who join in this grade.

NEW BRANCHES

It is proposed to form Local Branches of the Royal Aeronautical Society, with the object of extending to Members resident in the locality advantages similar to those more readily accessible to Members living within easy reach of London.

A Local Branch may be formed by the Council at the request of a number

of local Members of the Society, and may be dissolved by the Council. It will be governed by its own Committee with a Chairman, who must be a Fellow or Associate Fellow. The Secretary must be a Fellow, Associate Fellow or Associate. They will organise meetings, lectures, discussions and visits.

The Local Committee may enrol as Members of the Local Branch individuals unable to join the Main Society. Subscriptions of Members of the Main Society must be paid in full to Headquarters. Members of the Main Society who wish to take part in the activities of the Local Branch may be called upon for a small local subscription, which will be fixed by the Local Branch, and will be wholly available for local purposes. It is suggested that the local subscription should not exceed 5/- a year.

A Local Branch must consist of at least 20 Members, including Members of the Main Society.

A Local Branch shall be known as The ..... Branch of the Royal Aeronautical Society.

The assistance which the Society would give to a Local Branch would include :

1. Assistance in the arrangement of lectures and discussions or the repetition of lectures and discussions already given elsewhere. The Society in London may be better in touch with those who would be able to give the best lecture on a selected subject than would the Secretary of the local organisation. The arrangement of lectures to be given by officers detailed by the Air Ministry is probably more easily made through London than direct. Expenses in connection with these lectures, etc., will be borne by the Local Branch.

2. Members of a Local Branch would be entitled to attend all lectures and discussions of the Society in London.

3. Members of a Local Branch would have the use of the Society's Library for reference.

4. One copy of the Journal will be supplied to each Local Branch for reference. A further copy will be supplied for each 50 Members in excess of the first 50. Local Members may each purchase, through their Local Branch, one copy of each issue of the Journal at trade price.

Further particulars may be obtained from the Hon. Secretary.

CONVERSAZIONE

On January 12th, 1926, the 60th Anniversary of the foundation of the Royal Aeronautical Society was commemorated by a conversazione held at the Science Museum, South Kensington. The holding of the conversazione was largely due to a suggestion from Lieut.-Colonel Lockwood-Marsh. A very large number of the Society's members and their guests attended. The guests were received by the Chairman, Air Vice-Marshal Sir Sefton Brancker, who afterwards, in a speech introducing Sir Samuel Hoare, Air Minister, appealed for funds to enable the Society to increase its activities.

About 18 months ago the Society got into such low water financially that it had to allow its permanent Secretary to resign, said Sir Sefton. We now want to engage a permanent Secretary, and to do that we must have an assured income. The Air Ministry has generously given us a subsidy of £250 a year, the Society of British Aircraft Manufacturers have given us £250 and the Anglo-American Oil Company £50, and other big oil interests have promised to help us in future. A most valuable offer has been made by Lord Cowdray, who has promised £50 a year for five years on condition that nine other patriotic people do the same.

We have instituted a new grade, which is intended to bring in the practical men who are not qualified to be Fellows or Associate Fellows under the old arrangement. The new grade is called the Associate grade, and is open to pilot's licence "B," ground engineers, navigators (second class), works foremen, chief draughtsmen, chief inspectors, and that type of man engaged in the practical side of aviation. We propose to let them in without entrance fee and on the subscription of one guinea a year. The qualification of Associate of the Society will be something of real professional value.

Sir SAMUEL HOARE, the Air Minister, who was accompanied by Prince Chichibu of Japan, spent some time examining the exhibits, and then in the main gallery made acknowledgment of the place the Society occupied in British aviation. On his own behalf and on that of the Government generally, Sir Samuel Hoare said he was keenly interested in the anniversary, and wished to congratulate the Society on the invaluable work it had accomplished during the last 60 years. At the time of the Society's formation scarcely anyone believed in the future of aviation outside the membership, and even the Press was, with the exception of John Delane, extremely sceptical of the new development.

It was the Aeronautical Society, now the Royal Aeronautical Society, which kept the lamp of progress alight and year by year provided the opportunity, as its records of papers read showed, of discussing almost every problem of flying. Great as the record of the past 60 years had been, he hoped the most useful period of the Society's activities had yet to come. He understood that they were embarking on an extensive programme for the purpose of enlarging their activities, and were introducing an Associate Member grade, open to men and women who were not scientists, but were engaged daily in the work of flying. The new programme entailed greater financial support than that received during the past few years, and it was satisfactory to note that more than one benefactor had already come forward.

Mr. J. E. HODGSON, the Hon. Librarian, having briefly touched on the early work of the Society as a corporate body, briefly recalled the work of some of the more distinguished pioneers and workers, of earlier and of more recent times, who were members of the Society and some of whose models or machines were preserved in the Science Museum. Dividing them roughly into four groups, Mr. Hodgson (who explained that time did not allow of anything like an adequate review) first recalled the endeavours of the pioneer experimentalists—

F. H. Wenham, author of the first paper, his classic treatise on *Aerial Locomotion*, read before the Society; John Stringfellow, the "father of aviation"; Sir Hiram Maxim, who spent £20,000 on his great multi-plane flying machine; Lawrence Hargrave, who, with scant encouragement but remarkable pertinacity, carried out (near Sydney) hundreds of experiments with kites and flying machines, and Percy Pilcher, the first Englishman to give his life in trying to solve the problems of stability. Referring to the buoyant enthusiasm of these pioneers, Mr. Hodgson quoted as typical of their spirit, words applied to air travel in 1873 as "the swiftest, safest, surest, healthiest most delightful and cheapest methods of locomotion God has given to man." The second group included the military aeronauts—men like Colonel J. B. L. Templer, whose notable work, achieved in face of much indifference and obstruction, has not received its due recognition; Major Esdaile, who went out to Bechuanaland in 1883 with the first Army Balloon Detachment sent on active service overseas with a British force; Major-General Sir J. E. Capper, who was associated with S. F. Cody in the construction of the first British military dirigible, Cody himself earning greater fame by his heroic perseverance in the construction of his Army bi-plane; and A. V. Roe, whose machines have played so important a part in the training of military pilots. Turning to scientists and designers or engineers, amongst the former was mentioned the work of Professor G. H. Bryan, who was awarded the Society's gold medal for his work on the mathematical theory of stability; F. W. Lanchester, Dr. A. P. Thurston, and Professor Bairstow, while the latter included such familiar names as Dunne, Short, Sopwith, and Handley Page. Lastly there were the pioneer and test pilots, to whom were fittingly applied the brave words uttered by Dr. Johnson: "I will be conquered, I will not capitulate"—C. S. Rolls, Edward Busk, a fine scientist as he was a fine pilot, Graham Gilmour, Cecil Grace, B. C. Hucks, and E. M. Maitland, the latter affording a link with the heroism of pioneer work on airships, as the others serve in pioneer flight.

In conclusion, while emphasising the essentially scientific character of the Society's work, Mr. Hodgson expressed the hope that a measure of the splendid enthusiasm, pertinacity and determination witnessed in the work of those whose names had been recalled, would enter anew into the Society on this its sixtieth anniversary. And if by the exercise of their influence, as individual members not less than as an organised body, they helped to make it more clearly realised that this country, while remaining faithful to its great tradition as a seafaring race, must develop an "air sense" and become an air-faring people, then the Society would have added to its many great services to the Science of Aeronautics, no less great a service to the nation and to the Empire.

During the evening the band of the Royal Air Force played selections.

List of Guests and Members present:—

His Imperial Highness Prince Chichibu.
Mr. and Mrs. A. S. E. Ackerman.
Mr. Patrick Alexander.
Mr. C. E. Atkinson.
Flight Lieut. J. C. Atkinson.
Flight Lieut. L. A. Avery.
Major B. F. S. Baden-Powell.
Mr. and Mrs. R. M. Balston.
Miss Balston.
Mr. B. R. Banks.
Mr. and Mrs. A. Barclay.
Miss V. K. Barr.
Captain Beaman.
Mr. E. E. Beer.
Captain Berens.
Mr. and Mrs. A. E. Berriman.
Miss N. B. Birkette.
Major Percy Bishop.
Mr. and Mrs. Harris Booth.
Commander F. L. M. Boothby.
Major and Mrs. G. H. Brackley.
Air Vice-Marshal Sir W. Sefton Brancker.
His Excellency the Brazilian Ambassador.
Mr. and Mrs. Griffith Brewer.
Mr. Cyril Brewer.
Sir Charles Bright.
Lieut.-Col. W. A. Bristow.
Flight Lieut. G. M. Bryer.
Major G. P. Bulman.
Major P. W. S. Bulman.
Mr. Alfred Burgess.
Mrs. Busk.
Sir Geoffrey and Lady Butler.
Miss Butler.
Mr. Sydney Camm.
Mr. and Mrs. J. D. Campbell.

Miss M. Campbell-Perkins.
Wing Commander and Mrs. T. R. Cave-Browne-Cave.
Captain Charley.
Mr. Alan E. L. Chorlton.
Mr. H. L. Christie.
Mr. and Mrs. T. W. K. Clarke.
Mr. E. C. Classon.
Mr. R. Cobb.
Mr. C. G. Colebrooke.
Miss V. M. Cooper.
Professor J. D. Cormack.
Mr. and Mrs. J. Corthesy.
Mr. and Mrs. W. L. Cowley.
Mr. Val Cronstedt.
Lieut.-Col. M. O. Darby.
Mr. N. Davy.
Mr. and Mrs. J. B. Davy.
Major H. C. Davidson, U.S.N.
Mr. E. Dodson.
Captain Dodson.
Monsieur Charles Dolfus.
Mr. H. J. Edgar.
Mr. Stanley H. Evans.
Mr. P. F. Everitt.
Mr. A. Fage.
Mr. and Mrs. C. R. Fairey.
Mr. A. B. Fanstone.
Misses A. and F. Farrington.
Lieut.-Col. and Mrs. L. F. R. Fell.
Group Captain and Mrs. Fellowes.
Commander Fitzsimon.
Colonel and Mrs. J. D. Fullerton.
Commander and Mrs. Garbett.
Mr. S. E. George.
Mr. W. A. George.
Mr. E. C. Gibbons.
Mr. C. W. Gill.
Mr. H. L. Gladwell.
Major and Mrs. O. T. Gnosspelius.
Mr. J. N. Goldsmith.
Mr. Allan Gomme.
Mr. Arthur Gouge.
Mr. W. E. Gray.
Mrs. and Miss Gray.
Mr. C. G. Grey.
Mr. P. T. Griffith.
General A. Guidoni.
Squadron Leader R. A. de H. Haig.
Mr. F. W. Halliwell.
Mr. H. J. Cardnell Harper.
Miss Hartley.
Mr. James H. Hartley.
Dr. F. H. Hatch.
Mr. R. M. Hayes.
Professor H. E. Hele-Shaw.
Squadron Leader Hellyer.
Major and Mrs. H. Hemming.
Sir James and Lady Henderson.
Mrs. Roderic Hill.
Captain G. T. R. Hill.
Mr. C. Shireff Hilton.
Miss Shireff Hilton.
Commander M. Hirose.
The Secretary, Royal Historical Society.
The Rt. Hon. Sir Samuel Hoare, Bart., C.M.G., M.P.
Mr. J. E. Hodgson.
Mr. and Mrs. S. Hodgson.
Mrs. Hill Hodgson.
Mr. Charles Hodgson.
Mr. S. H. Hole.
Colonel H. S. Holt.
Mr. E. Hopkins.
Miss Horwood.
Mr. and Mrs. J. Howard.
Miss H. P. Hudson.
Mr. H. A. Hughes.
Mr. A. J. Hughes.
Mr. N. J. Hulbert.
The Hon. J. Huxham.
Mr. J. S. K. Inskip.
Miss E. Inskip.
Mr. H. B. Irving.
Miss Mercia Johnson.
Flight Lieut. and Mrs. Johnson.
Mr. K. Kato.
Major D. H. Kennedy.
Miss E. H. Kennedy.
Flight Lieut. A. C. Kermode.
Mr. R. L. Kirlew.
Mr. E. Gibson Knight.
Commander the Marquis and Marchioness Komatsu.
Captain and Mrs. A. T. Lamplugh.
Flight Lieut. H. Leedham.
Mr. and Mrs. M. Lewin.
Dr. C. Courtenay Lord.
Mr. John Lord.
Mr. G. Lyon.
Colonel and Mrs. H. G. Lyons.
Count and Countess Maeda.
Miss MacGregor.
Mr. H. J. Mackintosh.
Lieut.-Col. and Mrs. F. K. McClean.
Mr. S. J. Madden.
Mr. A. J. Makower.
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Mr. and Mrs. H. F. Marriott.
Lieut.-Col. and Mrs. W. Lockwood Marsh.
His Excellency Baron Matsui.
The Viscount Matsudaira.
Lieut. Commander Matsuki.
Mr. C. B. Matthews.
Mr. R. Borlase Matthews.
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Major T. B. Meyer.
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Captain J. Morris.
Mr. James Morrish.
Mr. F. C. Moss.
Mr. C. A. Mourant.
Mr. F. A. I. Muntz.
Mr. Basil Murray.
Mr. W. D. Murray.
Mr. J. L. Nayler.
Major Nerinox.
Miss Newton.
Mr. N. Norman.
Captain S. Okazaki.
Mr. J. S. L. Oswald.
Lieut.-Col. H. W. S. Outram.
Mr. and Mrs. G. L. Overton.
Mr. G. E. Page.
Mr. F. Handley Page.
Captain P. C. Passman.
Mr. C. Spencer Payne.
Group Captain R. Peel-Ross.
Mr. H. E. Perrin.
Mrs. H. M. Phillips.

Mr. E. L. Pickles.
Mr. R. F. R. Pierce.
Mr. R. C. Pierce.
Mr. C. A. Pike.
Mr. and Mrs. R. B. Pilcher.
Mr. G. Ponsonby.
Major and Mrs. H. Waymouth Prance.
Mr. R. L. Preston.
Captain Price.
Mrs. H. E. Pritchard.
Mr. J. L. Pritchard.
Captain Proctor.
Mr. D. R. Rye.
Squadron Leader Rea.
Mr. W. F. Reid.
Mr. and Mrs. L. G. S. Reynolds.
Mr. R. Rhodes.
Major L. F. Richard.
Mrs. Leslie Richard.
Lieut.-Col. V. C. Richmond.
Mr. H. G. Riddell.
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Mr. Frederick Small.
Lieutenant-Colonel R. Eccles Snowden.
Mr. T. O. M. Sopwith.
Mr. and Mrs. A. J. Spencer.
Mr. F. S. Spiers.
Mr. R. S. Stafford.
Mr. T. Stenning.
Mrs. and Miss Stenning.
Sir Edward and Lady Stephenson.
Mr. B. Stevenson.
Major O. Stewart.
Miss Lorna Swain.
Sir John Sykes.
Flight Lieutenant Sims.
Commander Y. Taji.
Mr. Y. Tanaka.
Mr. J. V. Tapp.
Mr. H. Kerr Thomas.
Dr. A. P. Thurston.
Lieutenant-Colonel and Mrs. H. T. Tizard
Captain and Madam T. Toyoda.
Mr. C. Travers.
Major C. C. Turner.
Captain and Mrs. F. Tymms.
Mr. H. T. Vane.
Major Villiers.
M. Vlaedimorof.
M. Voroshirof.
Sir Vyell and Lady Vyvyan.
Dr. and Mrs. H. C. Watts.
Mr. Bewley Weaver.
Brigadier-General J. G. Weir.
Sir Henry White-Smith.
Mr. G. S. Wilkinson.
Mr. D. L. Hollis-Williams.
Squadron Leader E. Howard-Williams.
Mr. H. E. Wimperis.
Mr. H. F. Winny.
Mr. C. G. H. Winter.
Mr. S. Wood.
Mr. and Mrs. R. McKinnon Wood.
Mr. H. N. Wylie.

PROCEEDINGS

SEVENTH MEETING, FIRST HALF, 61ST SESSION.

A meeting of the Royal Aeronautical Society was held in the Society's Library at 7, Albemarle Street, London, on Thursday, November 26th, 1925, when a paper on "Installation Problems in Air-Cooled Engines" was read by Mr. A. H. R. Fedden, Fellow. Air Vice-Marshal Sir W. Sefton Brancker, K.C.B., A.F.C., Fellow (Chairman of the Society), presided.

Before calling upon Mr. Fedden to read his paper, Sir SEFTON BRANCKER said: Gentlemen, I have to introduce to you to-night Mr. Fedden. If you do not already know him personally, you have, I am sure, all heard of him as one of the most distinguished engine designers in this country. Before the War he was engaged on the design of automobile engines. During the War he was working on the production of Rolls-Royce and Renault engines. In 1917, fortunately for us, the Air Ministry realised his abilities and found scope for his genius in the design of air-cooled engines for aircraft. When the War was over he joined the Bristol Aeroplane Company, where he designed and developed those remarkable air-cooled engines, the Jupiter, Lucifer and Cherub, which we all know so well to-day.

INSTALLATION PROBLEMS ON RADIAL AIR-COOLED ENGINES

BY A. H. R. FEDDEN, FELLOW.

1 *Introduction*

It is with some misgivings that I have ventured to present a paper on the installation of air-cooled radial engines, as at first sight this subject would appear to be the province of the aeroplane designer. As a result of further consideration, however, it is submitted that this important subject is a co-operative one, and that the engine-maker looking at the difficulties from another aspect may be able to bring new light to bear on the problems.

Despite the considerable attention given to it in recent years, it is believed that the great possibilities of the air-cooled radial are still not fully realised. This engine has such marked advantages over all other established types of aeroplane engines as regards weight saving, ease of production, simplicity of material, man hours for manufacture and overhaul, etc., that it would appear to be very well worth while to give the question of the installation of this engine every consideration.

It is a generally accepted fact that all new branches of engineering require a certain time for development, and must have different lines of thought brought to bear upon them before they can be perfected and brought to a satisfactory state of production. The accepted types of "in-line" water-cooled engines have had vastly more time and brains concentrated on their development and installation than have air-cooled radials, and consequently "the corners have been more rounded off" on this engine as regards its standardisation and installation.

The air-cooled radial has now arrived at a stage in its development where it can compare favourably with other existing types of engines as regards power/weight ratio and reliability, but I believe that much may yet be done to put the air-cooled radial installation on a better and more standardised basis, and it is with the idea of helping this work that this paper has been compiled.

These remarks apply particularly to the nine-cylinder single-row air-cooled radial, because I have been most intimately connected with this type during the last few years, but in most instances they may be applied also to other types of air-cooled engines.

2 *Engine Mountings*

Here is a part of the radial engine installation which at the present time shows considerable variation in design. At first sight this would appear inevitable, as a 400 h.p. air-cooled radial is to-day installed in such a wide range of machines. At one end of the scale this engine is found in a single-seater scout, where it must be tucked in as close as possible to the bulkhead to preserve manœuvrability, while at the other extreme, this same size of engine is installed in a large diameter fuselage machine, where the engine mounting must be much larger, and where there is ample room for accessibility.

Owing to this wide range of installations, therefore, it is admitted that engine mountings cannot be interchangeable, but so far from this ideal are we at present that it is quite usual to find very different types of mountings on exactly similar machines. It is submitted that greater standardisation over a range and additional saving in weight of the engine mounting structure might be obtained by investigating in some detail the requirements necessary.

From the engine-maker's point of view these would appear to be :—

(1) The mounting must be as light as possible.
(2) It must be strong enough to support the engine without serious deflection under all working conditions, and should be braced and gusseted according to the type of mounting in all bays.
(3) It must be stiff enough to withstand the torque variations of the engine, and the natural periods of the mounting and engine must not synchronise over the speed range of the engine.
(4) The mounting must not impose undue stress on the crankcase.
(5) If the mounting is attached to the fuselage by means of pin joints, these must have sufficient bearing surface, which surface is considerably more than is necessary from strength considerations. The pins should be a taper fit and ground.
(6) If the engine is spigot-mounted, the mounting plate must be true and a good fit to ensure maximum surface contact.
(7) The mounting must not interfere with the engine accessibility, and must allow of rapid removal of the engine from the machine.

Under the first heading, the smaller the type of machine, the greater the advantage the radial engine has over its competitors. I believe, however, that further reductions can be made in the weight of radial engine mountings, as I shall endeavour to show later on.

As an example of comparative installation weights on modern machines, the following Table No. I. showing the Potez 25 fitted with four types of water-cooled engines, and one type of air-cooled radial, illustrates the advantage in weight-saving of the latter.

TABLE NO. I.

COMPARATIVE WEIGHTS OF INSTALLATION UNITS—POTEZ 25.

	Make of Engine.				
	Jupiter.	Lorraine.	Renault.	Hispano.	Farman.
Normal b.h.p.	450	450	480	500	500
Dry weight of engine lbs.	730	840	1120	840	1230
Installation unit complete dry weight lbs.	900	1300	1543	1370	1675
Weight per b.h.p. of installation unit lbs.	2.00	2.89	3.21	2.74	3.35
Percentage weight per b.h.p. of installation unit	100	144.5	160.5	137	167.5

Table No. II. shows a tabulation of various engine mounting and cowling weights in terms of lbs. per b.h.p.

TABLE NO. II.

TABULATION OF WEIGHTS OF MOUNTINGS AND COWLINGS.

No.	Type of Plane.	H.P. of engine.	Type of engine and cooling.	Engine mounting. lbs./B.H.P.	Cowling lbs./B.H.P.
1.	Two-seater Fighter ...	300	8 cyls. V. W.C.	.186	.116
2.	Two-seater Tourer ...	240	6 cyl. W.C.	.22	.125
3.	Two-seater Fighter ...	270	12 cyl. V. W.C.	.144	.150
4.	Two-seater Fighter ...	300	9 cyl. Rad. A.C.	.062	.049
5.	Commercial Twin Engine	380	9 cyl. Rad. A.C.	.087	.073
6.	Commercial eight-seater	380	9 cyl. Rad. A.C.	.087	.14
7.	Two-seater fighter ...	400	9 cyl. Rad. A.C.	.062	.042

To fulfil the requirements under headings 2 and 3, the aeroplane designer requires to know :—

(*a*) The weight of the engine.
(*b*) The centre of gravity of the engine.
(*c*) The torque diagram of the engine.
(*d*) The polar mass moment of inertia of the engine.

In the past I am afraid engine-makers have not been as careful as they should have been in providing all the necessary information, and I believe that by so doing we ought to obtain lighter and better mountings. I am indebted to Mr. North for pointing out the importance of the heading (*d*), and to the R.A.E., Farnborough, for suggestions as to the methods and formulæ. The procedure existing in the shops of the Bristol Aeroplane Company to obtain this figure is, I think, of sufficient interest to merit a short description.

The polar mass moment of inertia of the engine in the case of the " Jupiter " is determined by the trifilar suspension method.

The engine is suspended with the crankshaft in a vertical plane, propeller end undermost, by means of three wires fixed equidistant from the crankshaft axis, the wires being of equal length and parallel to one another. Fig. 1 shows the actual details, the wires being attached by caps to three crankcase bolts at intervals of 120 degrees, and slung from a triangular plate. The engine is levelled by means of adjusting screws in the plate, and then made to oscillate through as small an amplitude as possible, approximately five degrees each side of its mean position. The time taken for fifty complete double swings is noted in order to obtain the periodic time. With the weight of the engine and the effective length of the suspension wires known, the polar mass moment of inertia of the engine may be obtained from the following formula :—

$$T = 2\pi / R \sqrt{IL/Wg}$$

T Periodic time in seconds for a complete double swing.
I Polar mass moment of inertia in lb. ft.
L Effective length of suspension wires in feet.
R Radius of suspension wires in feet.
W Weight of engine in lbs.
g 32.2.

The movement of the engine must be a purely oscillating one about the crankshaft axis and devoid of any lateral movement. It has been found by experiment that the angular position of the crankthrow is immaterial.

Some of the earlier mountings for radial engines were somewhat lacking in respect to No. 5. Hollow taper pins with a ground finish, however, will

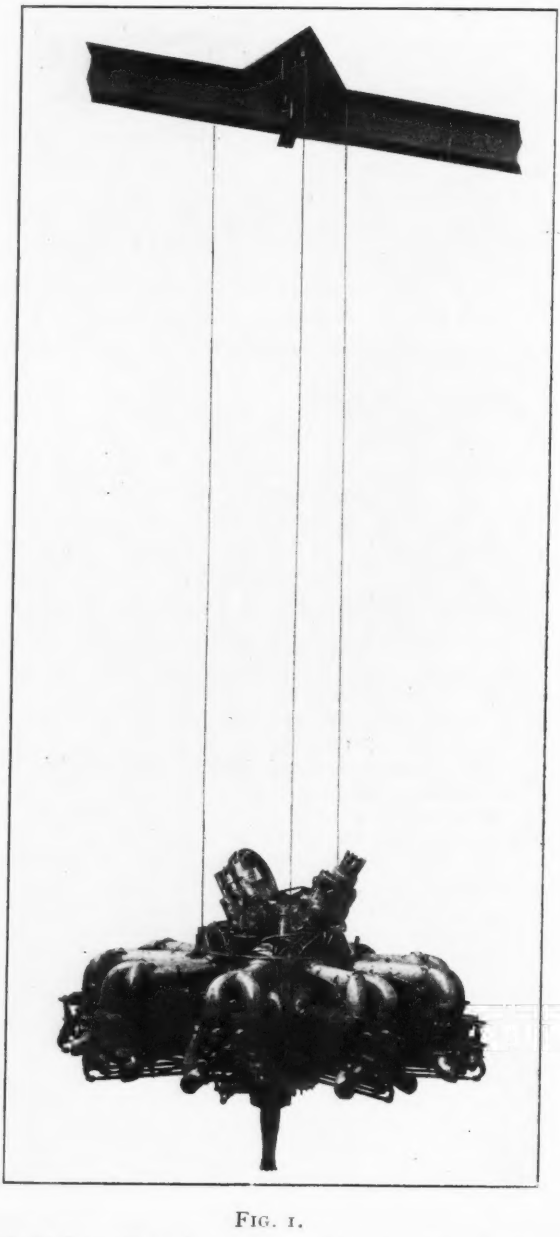


FIG. 1.

Method of obtaining the polar moment of inertia of the Jupiter engine,

provide a very great increase in bearing surface with a fractional increase in weight. Suitably designed spherical joints with adjustment for wear provide an excellent refinement for this attachment.

Under heading No. 7 it is very important to preserve one of the advantages of the radial engine, viz., the rapidity with which engine units may be changed in service. On similar types of machines I have found a considerable variation in this respect, and submit that here is a field for further improvement.

Three types of machines using " Jupiter " engines are employing duralumin for engine mountings successfully, and I think that this material is suitable for this purpose, and affords an appreciable saving of weight.

Figs. 2 and 3 show a selection of various types of engine mounting employed with the Bristol " Jupiter " engine.

The swinging type of mounting has not been very well received. I realise that it is not as light as the fixed type, but would appear to offer advantages on certain types of machine. Fig. 4 shows an example of this type of mounting —the Koolhoven F.K.31.

3 *Cowling*

Under this heading it is proposed to refer briefly to the normal type of cowling in use on current types of machines, and to deal with possible developments in this direction later.

The standard type of cowling in which some portion of the air-cooled cylinder head projects may be conveniently divided into two parts—the forward portion or fairing between propeller and engine mounting, and the rear part consisting of panels between the engine mounting proper and fireproof bulkhead on same.

On some of the earlier installations both portions of the cowling were rather unsatisfactory and flimsy affairs. As many of us know to our cost, there is far more in the design of sheet metal work to attain stiffness with light weight than is at first realised. Nearly all the earlier types of motor-car suffered in this same respect, and too often such work is left to be made up by hand on the job. I agree that on a first type the cowling can often more expeditiously be made up on the spot, but afterwards the form chosen requires very careful design work, to avoid localised stresses and consequent cracking, and also to cut down the production costs of panel beating, which are often a serious item.

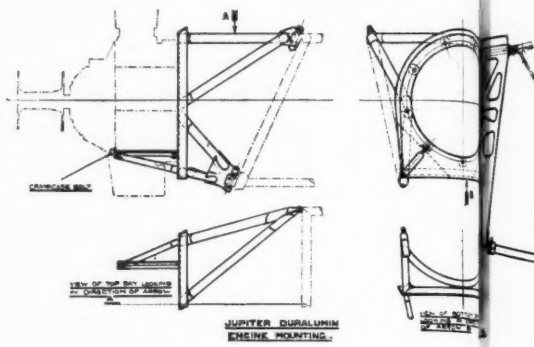
It is submitted that on a single-row radial it is not imperative that the front portion of the cowling or fairing should be immediately detachable. No portion of the engine inside this fairing requires frequent attention, and providing the method of attachment is practical, very stiff panels can be made up with press-tools with the minimum amount of hand work.

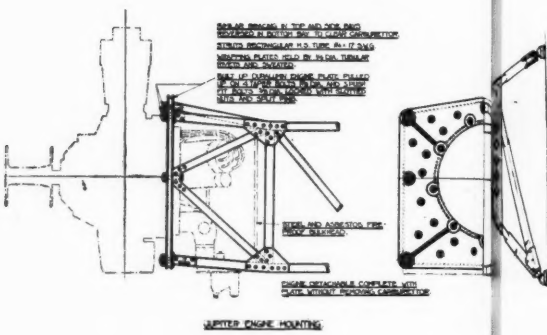
On moderate speed machines an air flow over the crankcase is necessary. On this type of machine when an exhaust ring is fitted, it is desirable to protect the inside face of the exhaust ring by a shield, which prevents the hot air from impinging on the crankcase.

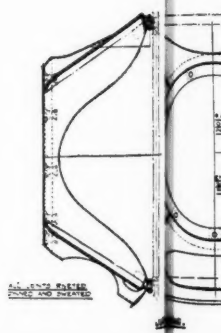
When considering the rear portion of the cowling, accessibility is of the utmost importance. We are all familiar with the type of panel positioned by a skewer, and its extremely difficult manipulation in the event of a hurried minor adjustment being necessary. The rear panels should be immediately detachable by means of some neat safety catch which is foolproof, will not drum, and which does not weaken the panel and cause localised stresses and cracking. There is scope for some ingenuity in detail design in this respect.

Fig. 5 shows a quickly detachable type of catch.

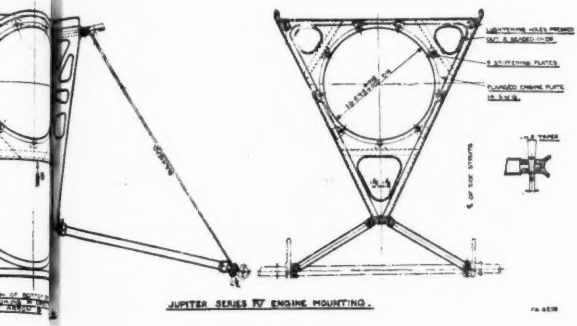
Fig. 6 shows the accessibility of the engine units with a detachable near panel.



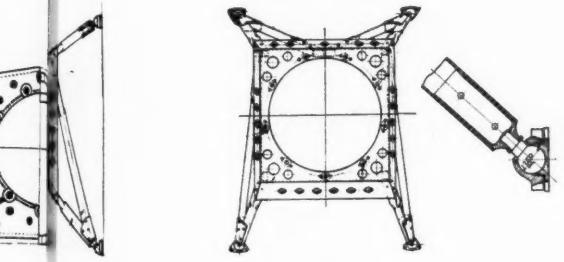




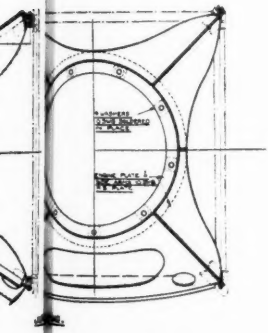
Diagrams of mounti



JUPITER SERIES IV ENGINE MOUNTING.



JUPITER SERIES IV METAL MOUNTING.



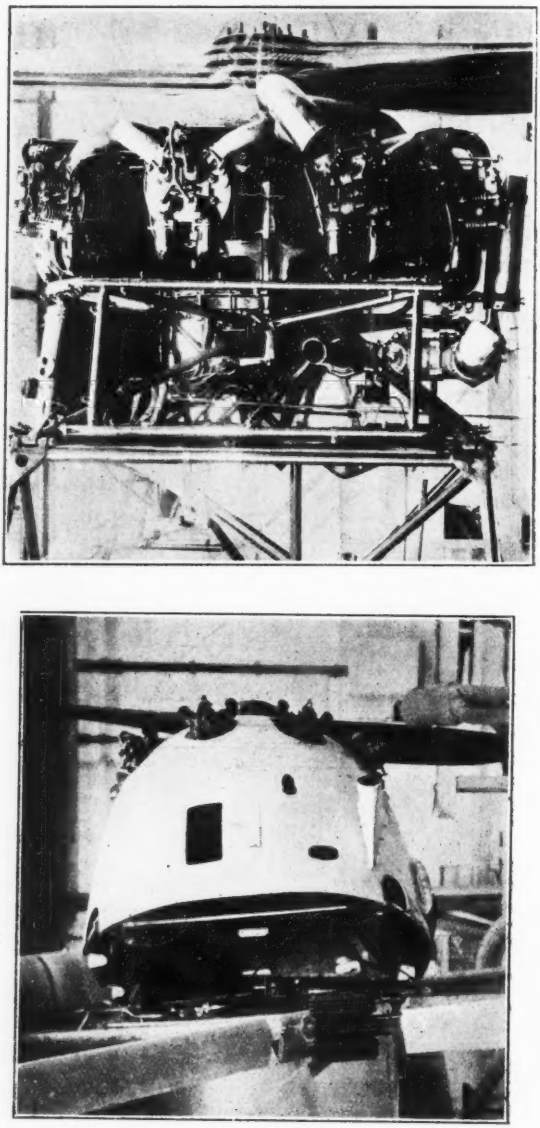


FIG. 3.
Jupiter engine mountings.

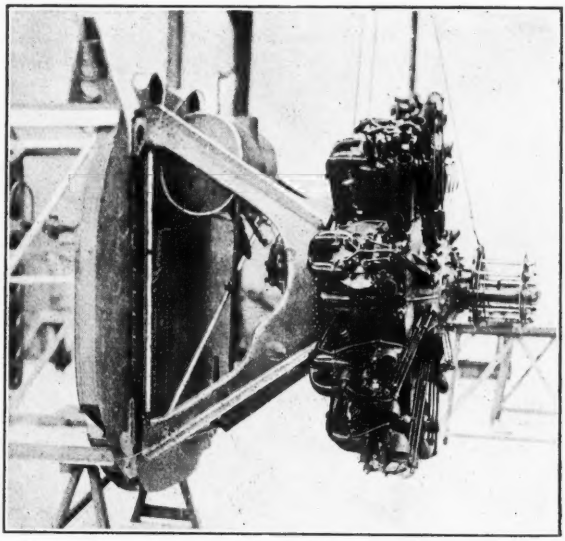
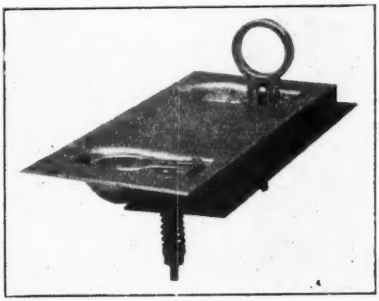


FIG. 4.
Koolhoven swinging engine mounting.



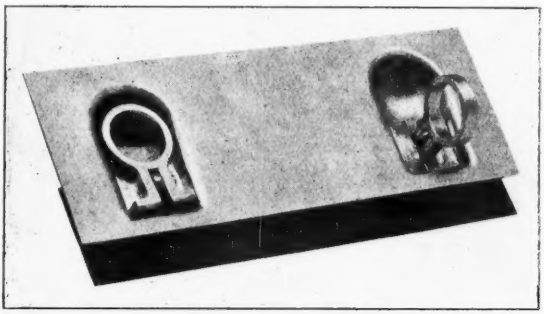


FIG. 5.
Quick detachable cowling clip.

For fighting aeroplanes the machine guns can be neatly arranged inside the cowling on the single bank radial, the arc of fire being between the cylinders, and the guns so placed that flash is eliminated, which is most important to prevent a blinding effect on the pilot.

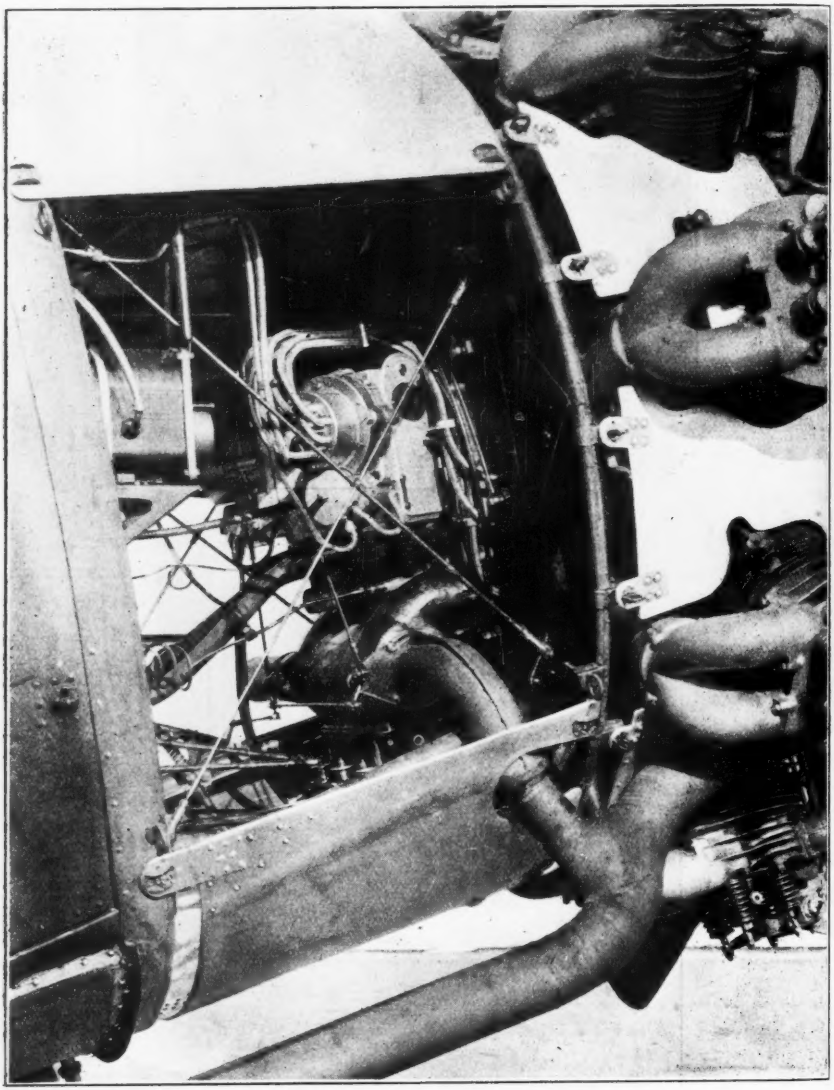


FIG. 6.

Showing accessibility of engine units.

4 *Spinners*

Spinners are a doubtful quantity from the engine-maker's point of view. While appreciating the desire of the aeroplane designer to provide a good entry, it is believed that most of the present type of metal spinners if large enough to be of much value are a very difficult manufacturing problem, and unreliable, and if run for long out of balance may set up serious stresses in the engine. It is realised that such spinners may have to be faced on future faster types of machines with air-cooled engines, in which case further attention must be given to their design.

The integral wooden type of spinner employed by Mr. Folland on his air-cooled installations seems to be an excellent compromise. There is scope for the nose shape in the event of no spinner being employed. See Fig. 7, Spad No. 51.

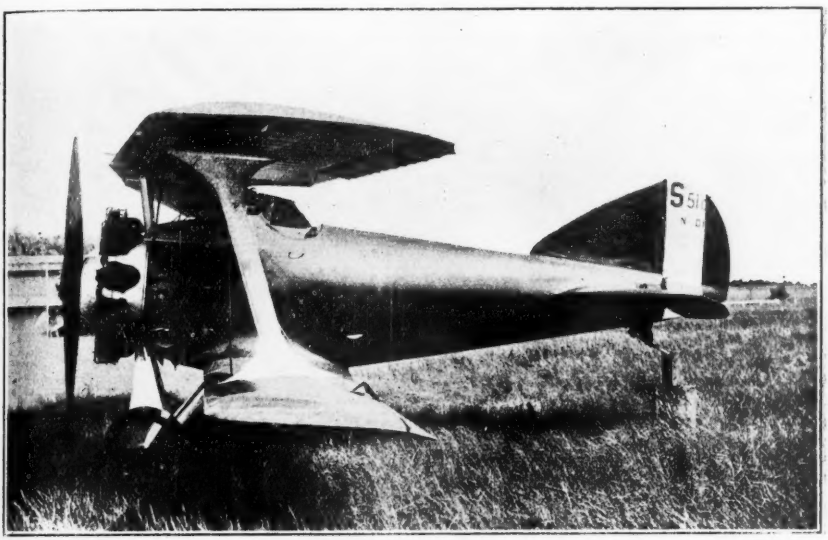


FIG. 7.
Spad 51.

5 *Exhaust System*

The solution of a satisfactory exhaust system for an air-cooled radial has been a great stumbling block in the past, and for some years it has been generally recognised that this type of engine could not be standardised on certain machines until this problem was properly solved.

The main reasons for an exhaust system are :—

(*a*) Flame damping at night to prevent a machine being seen, and the pilot dazzled when landing.
(*b*) To relieve pilot and passenger from noise.
(*c*) To assist wireless installation.
(*d*) To provide heating to cockpit in extremely cold conditions.

It is quite remarkable how difficult the solution of a satisfactory exhaust system has proved, partly because there is a good deal more to solve than was

at first realised, and partly because the responsibility was divided. It is believed that the most difficult part rests with the engine-maker, and as such it is submitted that it should be recognised as the engine-maker's problem.

The most suitable form of exhaust system for general use with an air-cooled radial is undoubtedly the ring or segment type, individual cylinders discharging

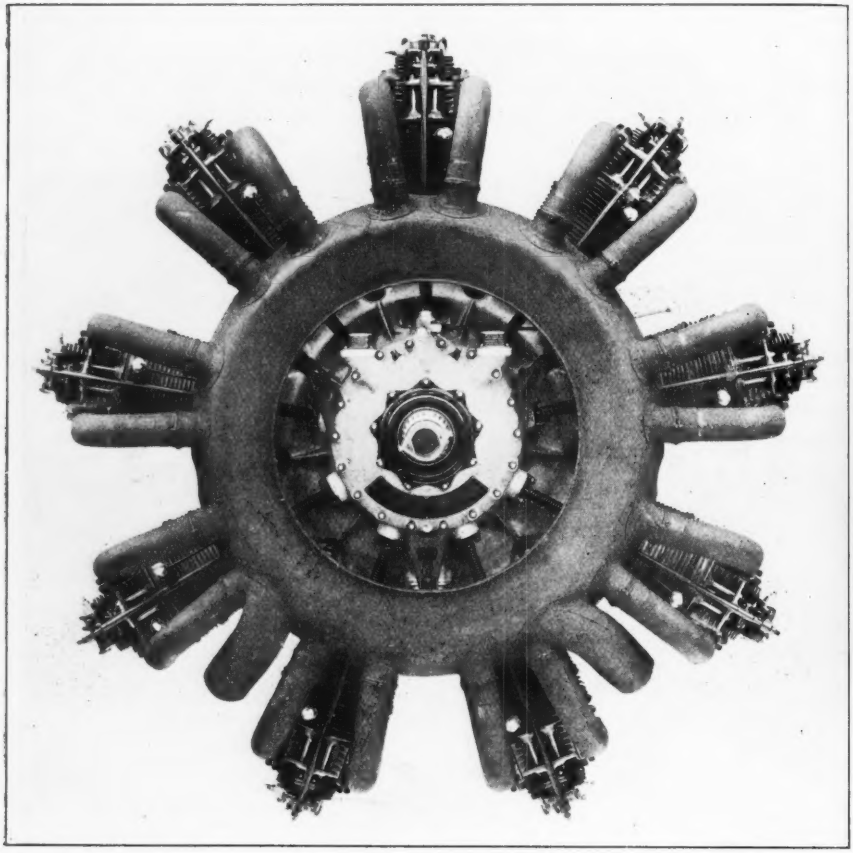


FIG. 8.

The Bristol Jupiter with Bristol small diameter exhaust ring.

direct into an annular form of collector provided with two main outlets discharging to atmosphere. For the satisfactory solution of such a system the most important requirements are:—

(*a*) Light weight, and the lowest drag possible.

(*b*) The system must be of sufficient volume not to cause back pressure and damage the valves.

(*c*) The system must be so designed that there are no sharp bends, or that the exhaust gases play directly on any portion of the expansion chamber. Either of these conditions produce localised hot spots, which make the system dangerous.

(*d*) The pipes from individual cylinders leading to the main chamber must be provided with flexible joints to allow for expansion of the cylinder heads.

(*e*) Welding to be used as sparsely as possible. If welding is necessary on the main expansion chamber, it should be riveted as well.

(*f*) The system as a whole must be sufficiently rigid to withstand any serious distortion, and robust enough for long service.

(*g*) The design must be such that it can be economically produced by press-tools and jigs, otherwise it is a very expensive component.

(*h*) The material from which the system is made should be stainless, to prevent internal corrosion and external rusting.

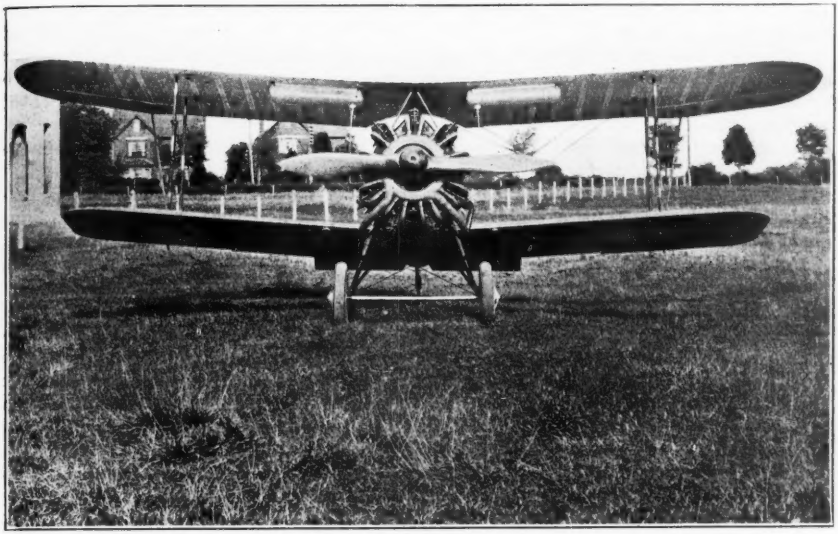


FIG. 9.

The Gloucester Gamecock with Jupiter engine.

The above list sounds rather formidable, but I do not think I have overstated the case. After some three years' experimental work, several designs and materials being tried out, a satisfactory exhaust system has been produced for the " Jupiter " engine, which has been extensively tested on the bench and in the air.

One ring has been tested for over 450 hours in flight without damage to the engine, or failure of the exhaust system.

Two types of ring are in production to be used according to the shape of the fuselage.

Fig. 8 shows the " Jupiter " engine with exhaust ring fitted.

Fig. 9 shows a front view of the Gloucester Gamecock, an example of a satisfactory solution of the exhaust system problem.

Assuming the exhaust system is produced by the engine-maker, close co-operation with the aeroplane designer is necessary on such details as cowling attachment, clips, etc., to prevent expensive changes to tools. It is considered that with a properly-designed exhaust system, there is less fire risk than with stub pipes, but from recent experience gained on water- and air-cooled engines, the safest position for the system is in front of the engine.

We require help from the metallurgist to produce a really stainless exhaust system for radial engines. The Bristol Company have been experimenting for some time with various brands of stainless material, but the production difficulties are greatly increased. Exhaust rings from partially stainless iron have been successfully made and tested, but with fully stainless material the results have been disappointing.

6 *Lubrication System*

Most modern types of air-cooled radial engines are fitted with a double spur gear pump unit, generally situated near the central axis of the engine. The delivery pump feeds oil under pressure to the important bearing surfaces of the engine, whence it drains to a supplementary sump from which the scavenge pump returns the oil to the main tank, or a cooler. It is not convenient to arrange the oil pump unit in such a low position as is common on water-cooled engines, hence the location of the main oil tank is somewhat limited. The tank must not be too low; in the case of the "Jupiter" engine the pressure pump will operate satisfactorily under all working conditions with a good pipe line system with an 18in. negative head; on the other hand the tank must not be too high, otherwise there is a danger of oil leakage when the engine is standing. In all ordinary climates no trouble has been experienced with a head of five feet. "Jupiter" installations and machines so fitted have been tested for long periods without oil leaking into the engine when standing. If the head exceeds five feet, a tap should be fitted between the tank and pressure pump. It is most important that this tap should be interconnected with the petrol cock or switch, in order to make it impossible to run the engine with the oil off. With the rather short pipe lines on radial engine installations it is very necessary to guard against sharp bends and traps, as these defects will have a serious effect on the system in cold weather, even if they are not discovered under ordinary climatic conditions. Screwed metal oil pipe connections should be used, but it is most important that flexible joints should be introduced in the piping, otherwise rigid screwed joints are a source of danger.

In all types of modern air-cooled engines the maximum oil circulation possible is desirable and general practice in order to ensure passing as much oil as possible through the bearings and engine generally. Further, as the relative surface of the crankcase is small and often covered in by cowling, oil coolers are necessary.

The following Table No. III. represents the working conditions of the oil on a "Jupiter" IV. on the test bench:—

TABLE NO. III.

Specific gravity of oil used	=	.94
Specific heat of oil used	=	.434
Weight of oil circulated	=	8.06 lbs./min.
B.T.U.'s added to oil	=	357 min.
H.P. lost	=	8.4

On the test bed under full throttle conditions oil is supplied to the engine at a given regulated temperature, viz., 55°C., and leaves the engine at 90°C. to 93°C., or with an entirely cowled engine at 100°C. to 103°C. This shows an increase in oil temperature of 35°C. to 45°C., according to the engine installation.

Contrary to general opinion, no damage can occur to the engine or oil at these temperatures, providing the oil is immediately cooled before being redelivered to the engine; hence the necessity for oil coolers and oil thermometers; the oil should not exceed 70°C. on re-entering the engine.

To deal with this increase in temperature the Bristol Company have developed a series of oil coolers of varying sizes and types, according to different installations. These coolers require very careful manufacture and selection of correct materials. The Bristol type of tubular coolers are tested to 80 lbs. pressure, and made from copper tube 28 gauge.

These coolers are self-regulating by means of a by-pass valve, which also acts as a safety valve.

Different sizes of cooler are necessary according to climbing speed of the machine and time taken on full throttle to a given height.

Table No. IV. gives particulars of the three coolers :—

TABLE NO. IV.

Type.	Lbs. weight of cooler.	Oil temp. drop over cooler under similar conditions.	Class of machine for which suitable.
No. 1	3·25	26°C.	Fast single-seater.
No. 2	5·25	36°C.	Moderate speed two-seater.
No. 3	8·5	45°C.	Slow machines, or for machines in very hot climates.

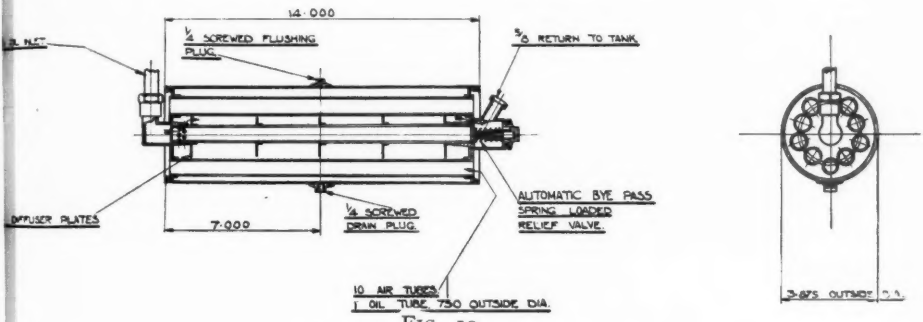


FIG. 10.

Bristol oil cooler, No. 1 type.

Fig. 10 shows No. 1 cooler.

Fig. 11 shows a satisfactory lay-out for the lubrication system of a radial engine.

Oil strainers should be mounted, and cowling panels so arranged that strainers can be examined regularly without having to break any oil connections.

In the above notes I have endeavoured to outline the points to watch on the lubrication system of an air-cooled radial. The oil coolers described above function satisfactorily, but I am quite convinced that there is still more work to be done on this part of the installation. We must obtain the necessary oil cooling without the drag and weight of the present coolers. This can be accomplished by one, or a combination of the following schemes :—

(*a*) Incorporating the cooler in the main tank.
(*b*) Incorporating the cooler in the fairing of the body.
(*c*) Using the hot oil to preheat ingoing gases.

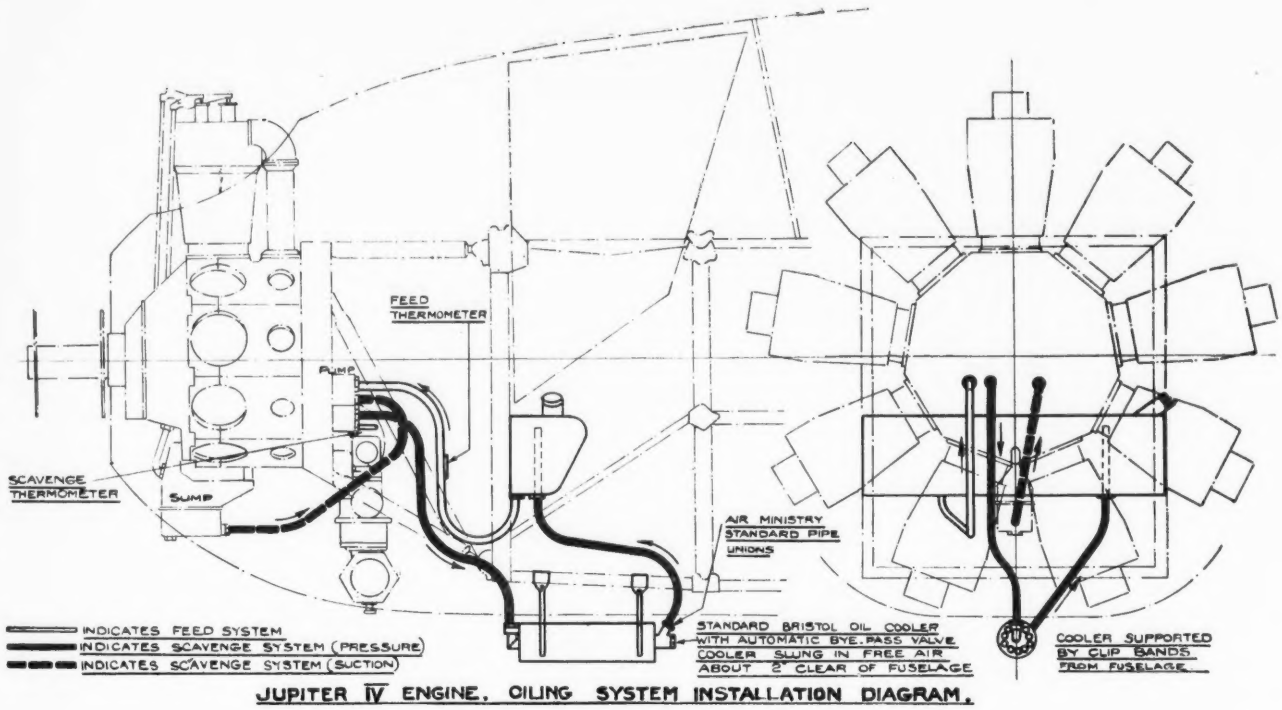

FEED THERMOMETER
PUMP
SCAVENGE THERMOMETER
SUMP
AIR MINISTRY STANDARD PIPE UNIONS
INDICATES FEED SYSTEM
INDICATES SCAVENGE SYSTEM (PRESSURE)
INDICATES SCAVENGE SYSTEM (SUCTION)
STANDARD BRISTOL OIL COOLER WITH AUTOMATIC BYE-PASS VALVE COOLER SLUNG IN FREE AIR ABOUT 2" CLEAR OF FUSELAGE
COOLER SUPPORTED BY CLIP BANDS FROM FUSELAGE
JUPITER IV ENGINE. OILING SYSTEM INSTALLATION DIAGRAM.

FIG. 11.

Jupiter Standard oil system installation.

Jupiter Standard oil system installation.

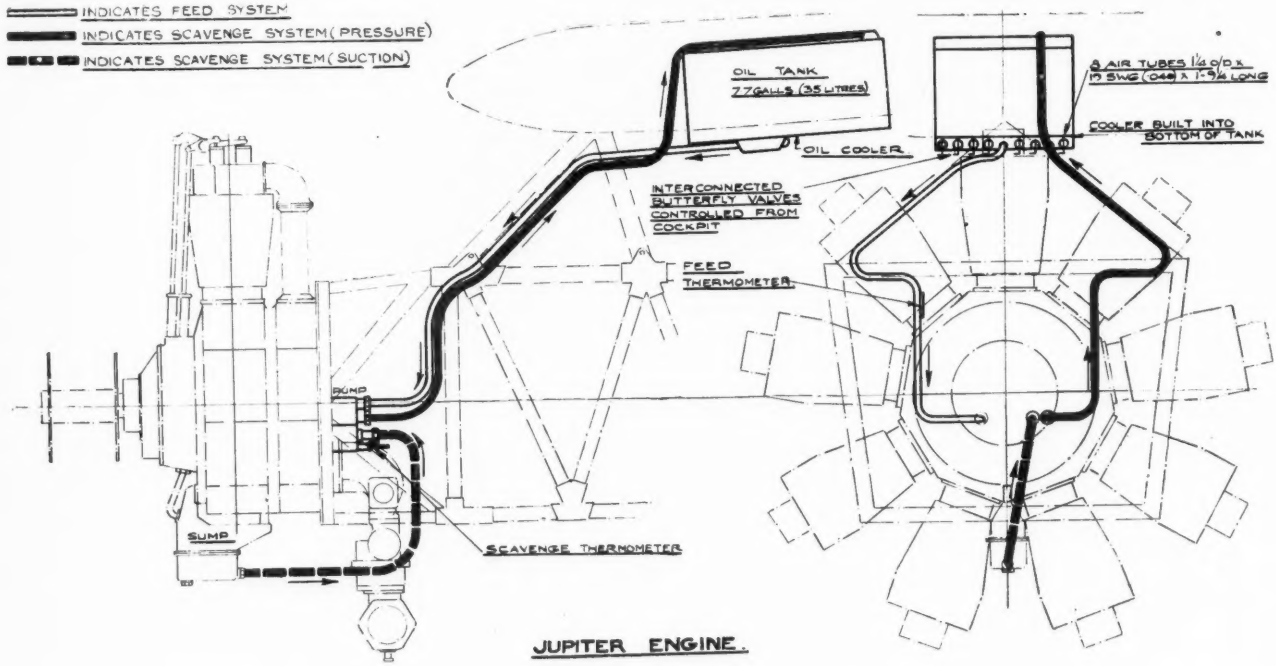


FIG. 12.

Combined oil tank and cooler.

Some of these schemes are already on the way. Fig. 12 shows a cooler incorporated in the tank, and Fig. 13 the new " Jupiter " oil cooler for the air intake.

The separate oil cooler has had to serve up to the present, but the question of oil cooling must be further investigated and standardised so that we can cool the oil without having the other disadvantages, which conditions are, I am sure, quite possible.

7 *The Carburation of Air-Cooled Radial Engines*

Air-cooled radial engines are somewhat more susceptible to change in temperature, insomuch as the air-cooled engine is not at present provided with the temperature control by means of shutters or thermostat standardised on water-cooled engines. Add to this the fact that in the latest type of air-cooled radial installations the engine may be running on the ground at an air temperature of +6°C., and ten minutes later may have to function at altitude at a temperature of —49°C., some of the carburation difficulties will be realised.

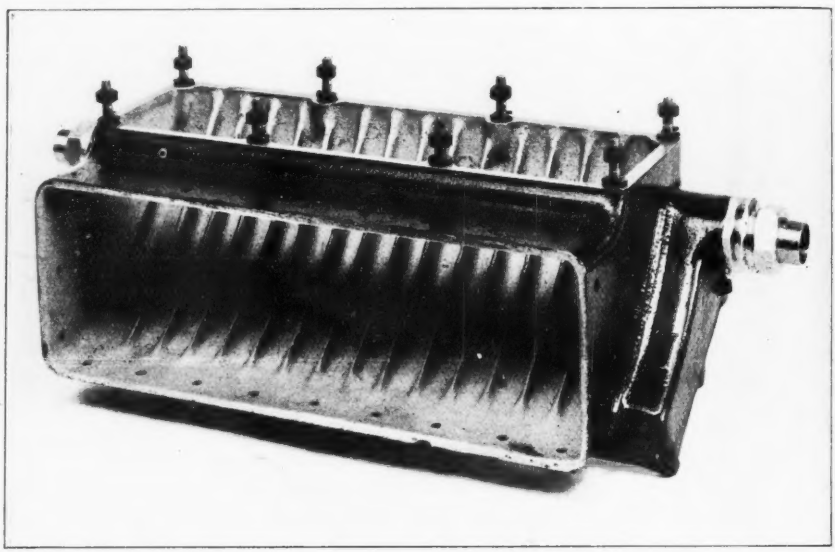


FIG. 13.
Oil heated air intake.

I think this difficulty is to some extent responsible for the statements that early air-cooled engines fell off in performance abnormally at altitude. We have made considerable improvement in the carburation of air-cooled engines at altitude, but I am sure there is much still to be done. Here again the difficulty has been one of a divided responsibility, and I believe that by close co-operation we can obtain still better results with reduced weight.

The Bristol " Jupiter " engine has a combination of exhaust heating to the induction elbow, and warm air and oil heating to the air intake. It is obvious the less preheating of the mixture the better, as this reduces the volumetric efficiency of the engine, but a certain amount is unavoidable to prevent condensation and consequent freezing under varying conditions at altitude.

In warm climates and low altitudes very little heating is necessary, but in cold climates and at high altitudes considerably more heating is necessary. Table No. V. will show comparative results with different kinds of heating on a Series IV. "Jupiter" engine at normal revolutions :—

TABLE NO. V.

"JUPITER" SERIES IV. VARIOUS FORMS OF HEAT APPLICATION TO INDUCTION SYSTEM.

Particulars of Test.	Atmospheric temp.	Temp. in air intake.	Temp. of mixture in induction pipe.	Rise of temp. of mixture in induction pipe.	B.H.P.
1. No extraneous heating.	16°C.	16°C.	24°C.	8°C.	398
2. Exhaust heating.	16°C.	16°C.	29°C.	13°C.	396
3. Oil heating only.	16°C.	16°C.	25°C.	9°C.	399
4. Exhaust heating and warm air intake.	16°C.	19°C.	34°C.	18°C.	394

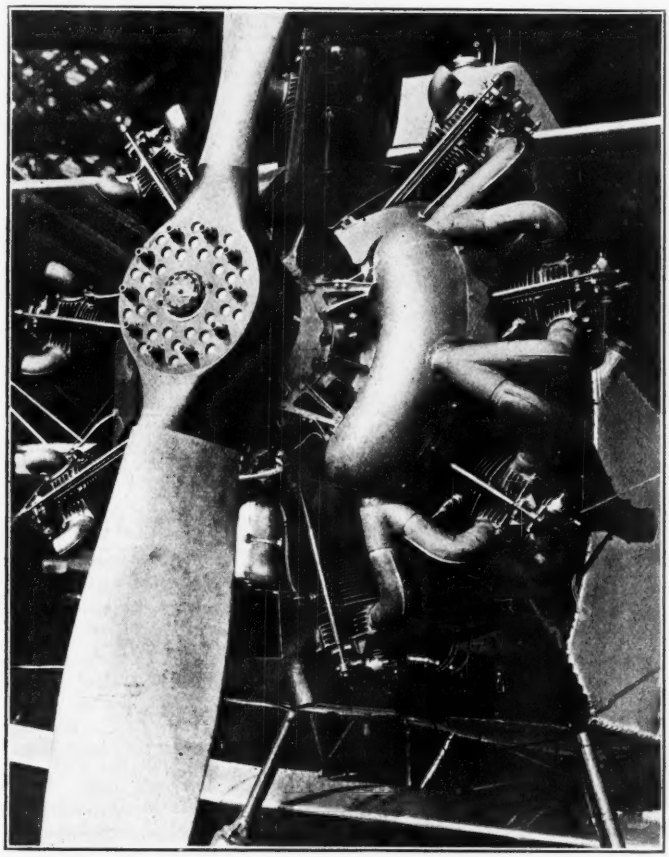


FIG. 14.
Installation for Arctic conditions.

For commercial work No. 2 is satisfactory, whereas No. 4, which has been found most suitable for all the year round flying at various altitudes, shows an appreciable drop in b.h.p. at ground level.

Fig. 14 shows a special arrangement for variable heating control necessary for Arctic conditions. This scheme can undoubtedly be cleaned up, and is only shown to demonstrate extreme carburettor conditions.

There is still a further carburation condition to be met at altitude with radial engines, viz., rapid acceleration after throttled running, which is provided for in the water-cooled installations by shuttering the radiator.

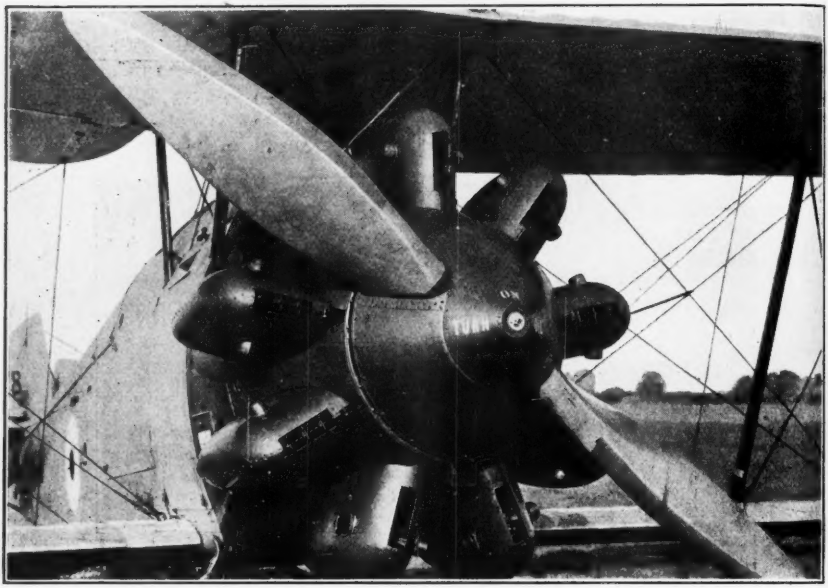


FIG. 15.

The Parnall Plover with Jupiter engine, showing cylinder helmet cowling with variable shutters.

Such conditions can certainly be met, and Fig. 15 shows an interesting experimental type of cowling on the Parnall Plover with "Jupiter" engine. It will be seen that variable shutters are provided to each cylinder, and the air intake is through slots on the bottom cylinders.

Special air intakes are necessary on seaplanes, and machines used in the desert, to prevent the ingress of water or sand. Fig. 16, the Hawker "Hedgehog" with "Jupiter" engine, is a good example of this type of air intake.

Butterfly throttles are fitted on modern air-cooled radial engines, and owing to the fiercer acceleration when opening up for taxying with this type of throttle compared with the barrel type, the control levers should have as slow a movement as possible for the first part of their travel. Particulars of a suitable connection for the control levers to give this result are shown in the installation drawings which the Bristol Aeroplane Company issue.

For altitude control I consider jet control is more positive and progressive than vacuum control. There is also the further advantage that with this type of control, and a warm air intake, the danger of blocking the air intake with snow is eliminated. Snow in air intakes with an air balance pipe control is fatal.

Fig. 17 shows details of the latest type of "Jupiter" air intake. It is desirable that this type of air intake is provided with a suitable petrol drain.

Flexible connections on the petrol pipe system are in my opinion absolutely necessary, although metal connections should be used to tanks and carburettors.

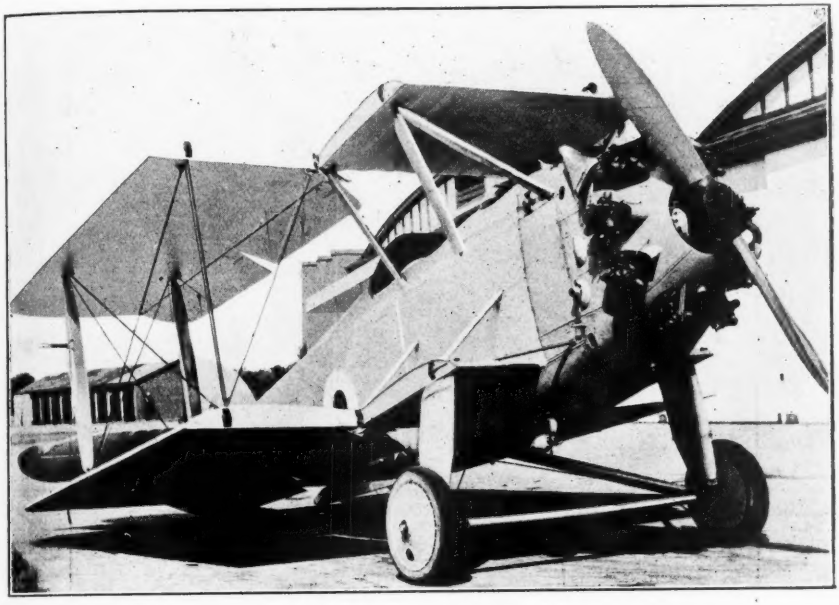


FIG. 16.
Hawker Hedgehog with Jupiter engine.

8 *New Types of Air-Cooled Radial Installations*

So far I have endeavoured to deal with some of the main outstanding points on existing installations, but I feel that we in this country may not realise fully the advantages of possible new types of installations for air-cooled radials. With the exception of the Boulton & Paul "Bugle" with two "Jupiter" engines, and the Handley Page "Hampstead" with three Jaguar engines, which have lately been produced, I do not know of any serious attempts to produce multi-engined radial installations. I believe there are very great possibilities in this respect. The greater the number of engines used, the more outstanding the advantages of simplicity, low weight, cheapness and ease of installation of the air-cooled radial are brought out.

Figs. 18-24 will show some interesting applications in this respect.

Amongst these installations will be noted a tandem one, showing one "Jupiter" engine used as a pusher. I realise this type of installation is not popular in this country, and dare not express an opinion myself as to the aero-

dynamic " pros and cons " of such a machine, but I have ventured to show this as from figures obtained from this installation extremely good results are claimed over a period of sixty hours' testing, and no trouble whatsoever has been experienced with the rear engine. If this tandem scheme were found to be worthy of reconsideration, the difficulty of using full throttle with the rear engine in the case of the forward engine being out of commission is not insurmountable; tests have already been made at the Bristol Company which show that the necessary alterations can be made to the engine to make full throttle possible under the above conditions.

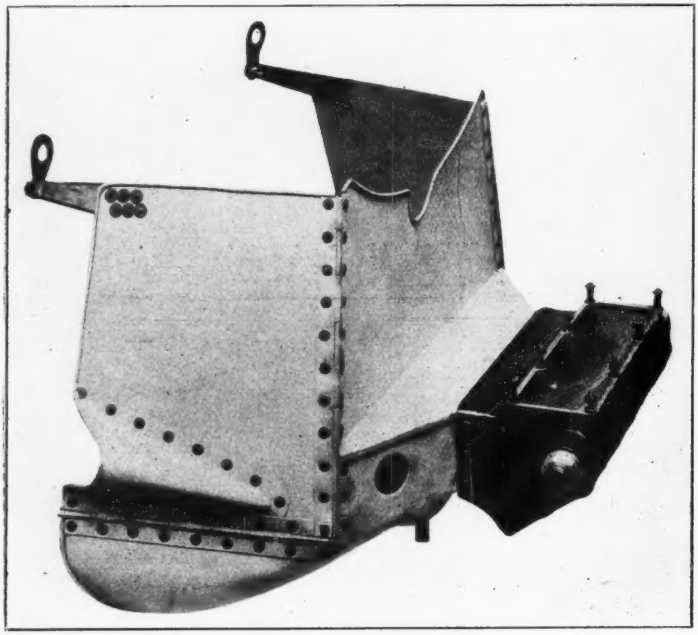


FIG. 17.

Jupiter combined air intake and oil cooler, drawing warm air off the cylinders.

9 *Possible New Type of Air-Cooled Engine Installations*

It is realised that in the past the aeroplane designer has had to make the best installation he could with the air-cooled radial engines provided. Even with what has been already achieved the air-cooled radial provides a power unit with the lightest weight, lowest structure weight, permitting of the best manœuvrability and the best position for the pilot.

It may be interesting to see the progress made in weight reduction and power-weight ratio on the Bristol " Jupiter " engine during the last four years. Fig. 25 gives these figures.

Without wishing to be too optimistic, I believe these figures can be considerably improved with corresponding reductions in frontal area.

Air Chief Marshal Sir Hugh Trenchard, in his address to the Cambridge University Aeronautical Society last April, pointed out that in the event of

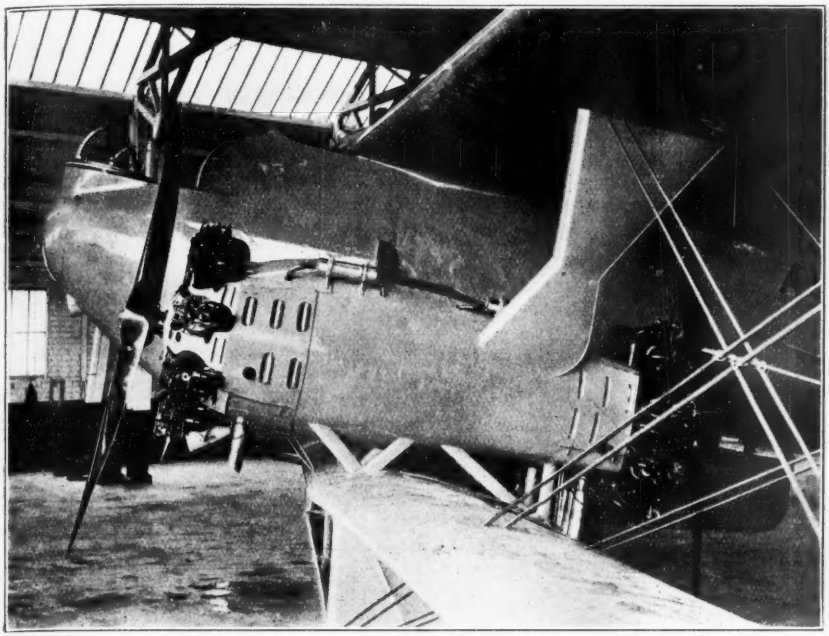


FIG. 18.
Jupiter four-engined machine, Latecoere.

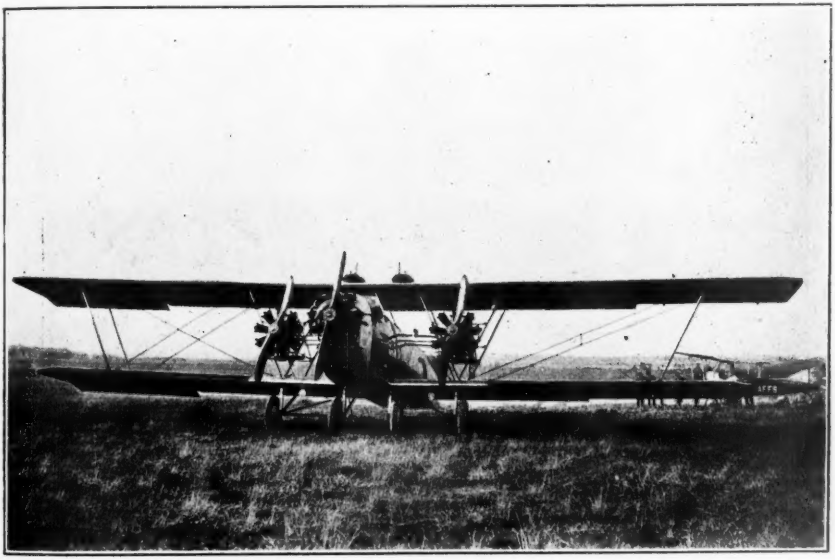


FIG. 19.
Jupiter three-engined machine, Potez.

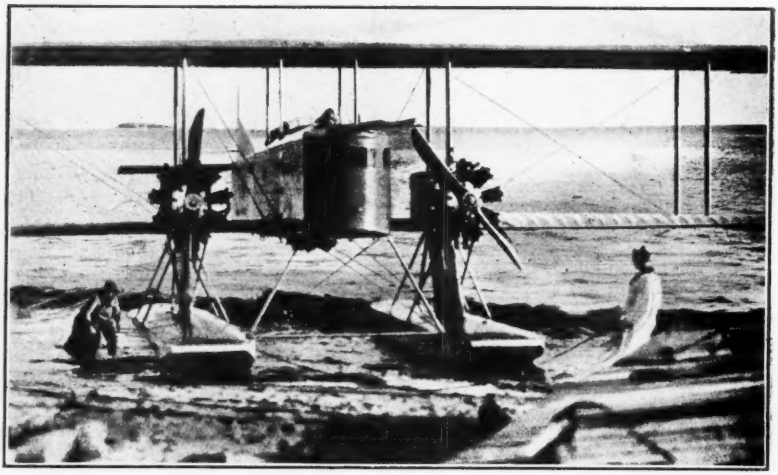


FIG. 20.
Jupiter twin-engined seaplane, Farman Goliath.

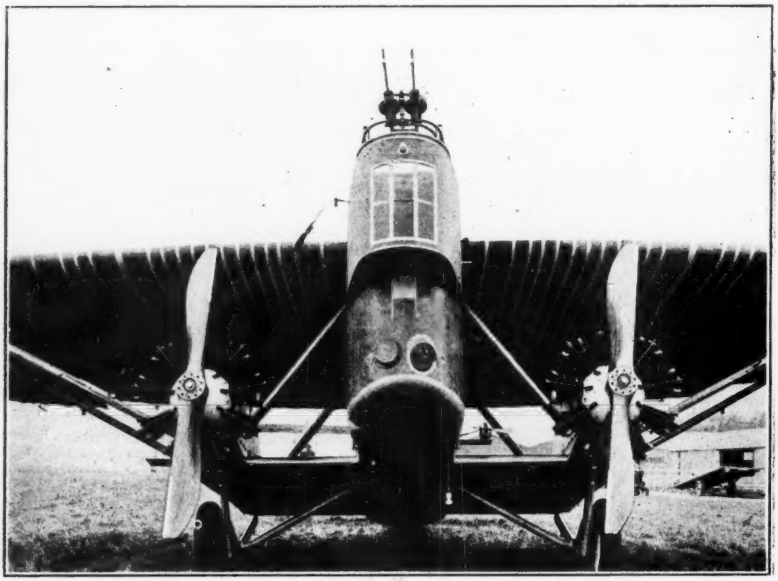


FIG. 21.
Jupiter twin-engined machine, Farman Jabiru.

another war the wastage of aeroplanes would be so great that that country which could most rapidly re-equip itself would most probably win the war. If a really large output of 400 to 450 h.p. engines were required at short notice, I submit there is no answer to the problem at the present time, except the air-cooled

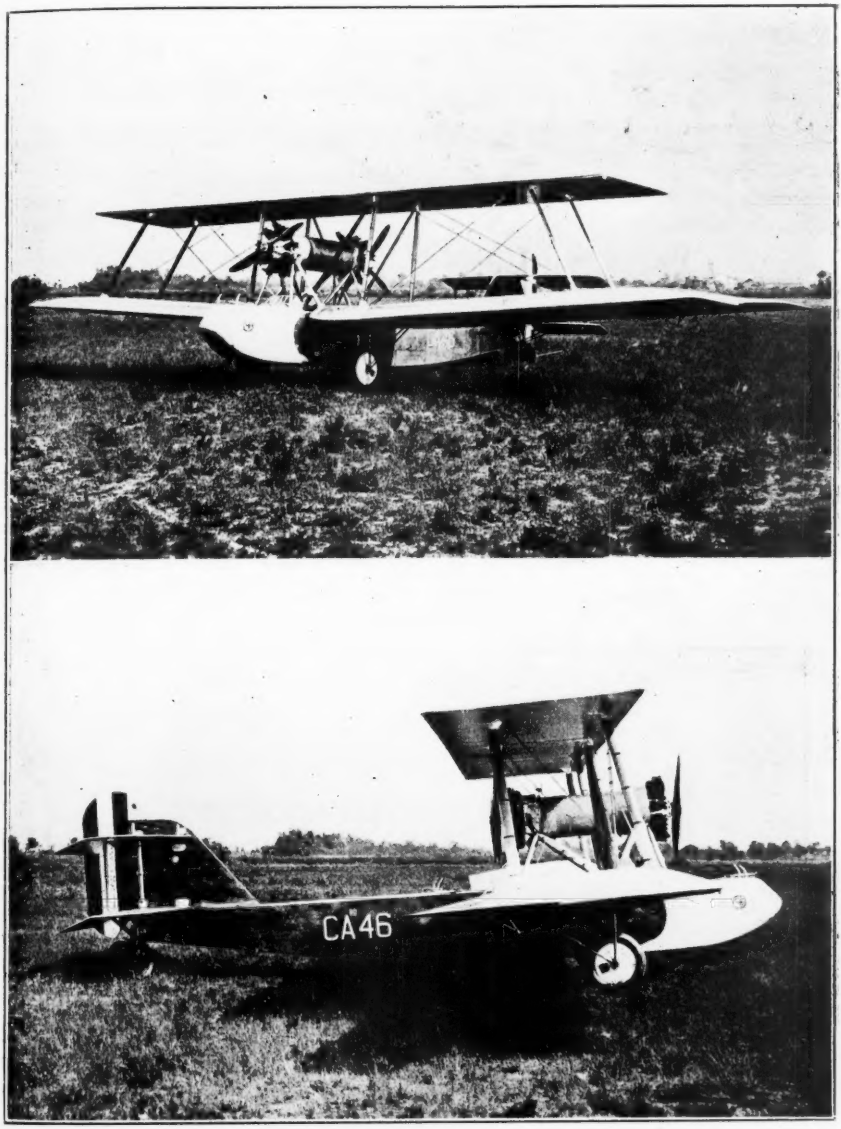


FIG. 22.
Jupiter twin-engined machine, Caproni.

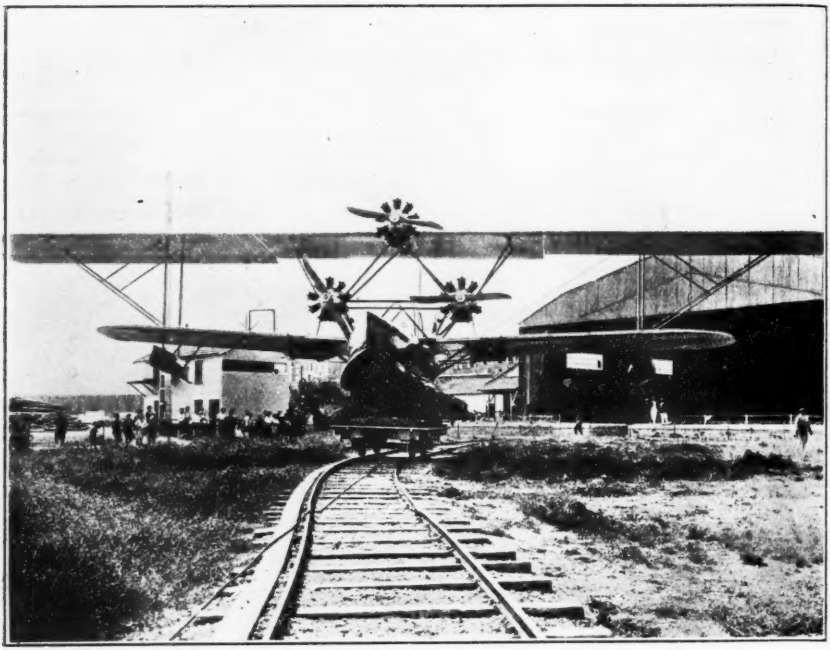


FIG. 23.
Jupiter three-engined machine Liore et Olivier.

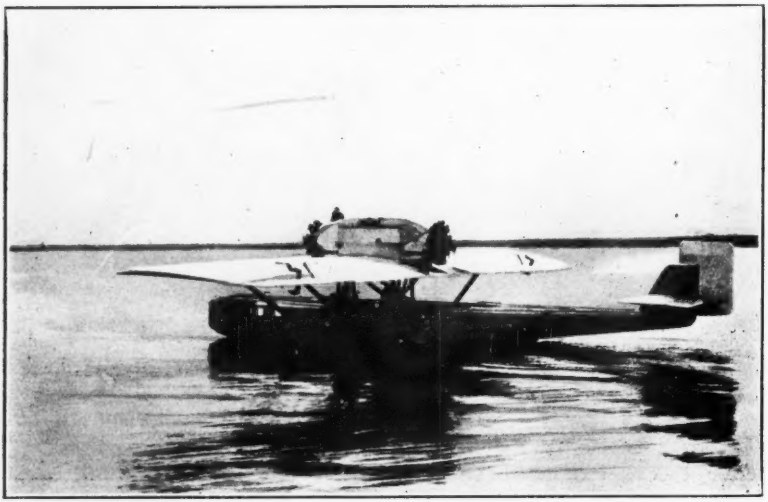
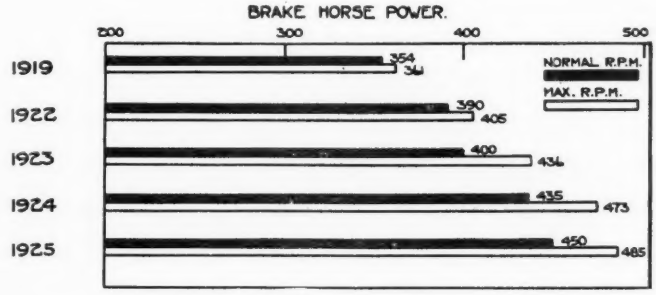


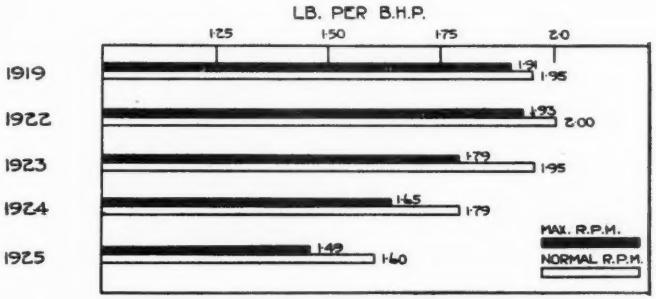
FIG. 24.
Jupiter twin-engined flying boat, Dornier-Wal.

radial. With these very definite advantages in favour of the air-cooled radial, it seems desirable that every effort should be made to obtain co-operation between the aeroplane and engine designer with a view to bringing the installation of this engine to a higher stage of perfection.



THE BRISTOL JUPITER ENGINES.

POWER DEVELOPMENT CHART.



THE BRISTOL JUPITER ENGINES.

POWER-WEIGHT RATIO CHART.

FIG. 25.
Jupiter development chart.

It has lately been put forward to me that irrespective of diameter and consequent drag, the blunt nose of the radial engine on high-speed machines is a serious drawback. If such be the case, I see no reason why the radial air-cooled engine designer should not improve this by suitable design in co-operation with

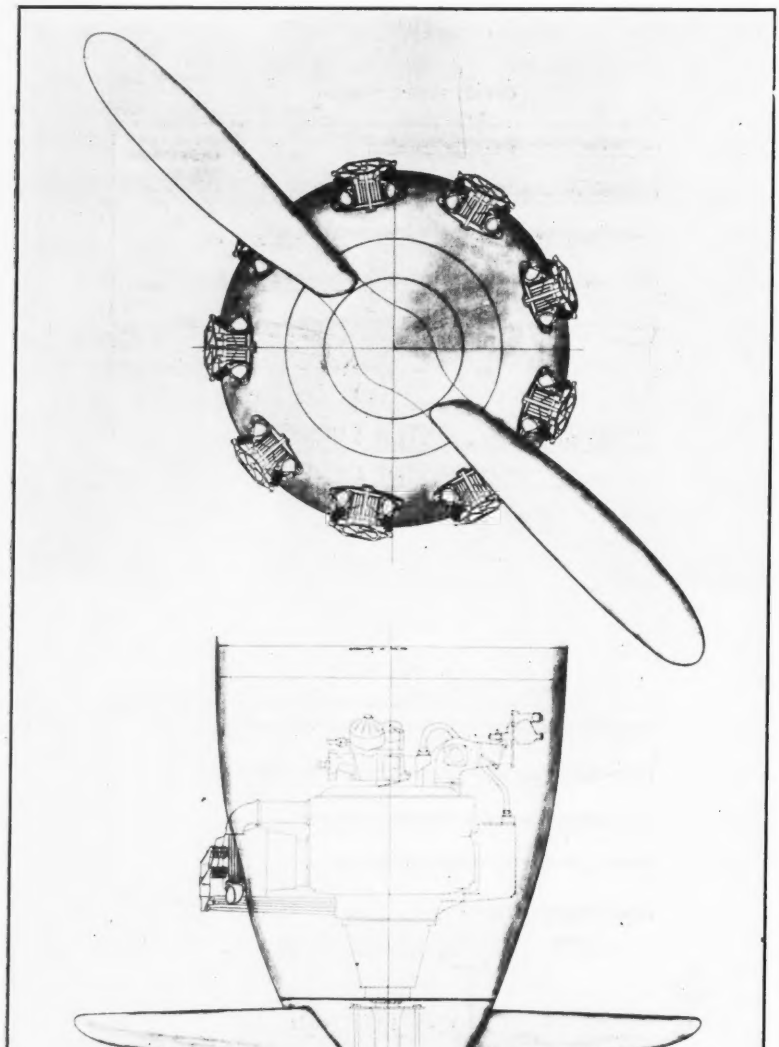


FIG. 26.
Suggested cowling scheme for Jupiter high-speed machine.

the aeroplane designer. Further, I see no reason why the air-cooled radial engine should not be entirely cowled in, which, as you are probably aware, has already been attempted experimentally in two or three cases. To meet these conditions, however, modifications in design are necessary.

Fig. 26 shows a suggested scheme to improve the installation of an air-cooled radial engine for high-speed machines.

Discussion

Before opening the discussion, Sir Sefton Brancker read written contributions to it from Mr. Folland and Mr. North, and continued: I was very glad to hear that Mr. Fedden thinks he has solved the question of preventing snow choking the intake pipes. I have had two personal incidents of engines being choked with snow, and ever since then I have been worrying the Technical Department to discover a means of eliminating this danger. Mr. Fedden claims to have solved the problem, and in my opinion, if he has succeeded, he has made a most important step in the progress of civil aviation.

From a commercial point of view, the possibility of rapid and easy replacement of an engine is a considerable financial asset. Really good installation should enable you to remove an engine very rapidly, and I should be much interested to know what amount of time he thinks ought to be necessary for the removal of a Jupiter engine given one of the installations he has shown us to-night.

While talking about the difficulties of installing air-cooled engines, and in particular the difficulty of streamlining them, I should like to mention a case I came across the other day. Mr. Cobham is flying to South Africa in the machine he used on his Eastern flight, but has replaced the Puma engine with a Jaguar. The Puma installation was described as a really good streamline job; the Jaguar in appearance could not compare with it. Mr. Walker, of the de Havilland Company, told me that the performance of the machine with its new engine was worked out carefully beforehand, but without taking into consideration the difference of streamlining involved by the fitting of the Jaguar engine. The machine gave exactly the performance they had calculated, which seems to indicate that the somewhat clumsy looking Jaguar installation is just as efficient as the nice looking Puma installation.

It is rather sad to see Mr. Fedden's slides of a long succession of Jupiter engines, all on French, German, Dutch and Italian machines. The Lecturer, however, is not quite right in saying that the only multi-engined machine in England fitted with air-cooled engines was the Handley Page Hampstead. The Siddeley Argosy is fitted with three Jaguars also. There is also a small Handley-Page being developed with three Lucifers. I tried to get a machine with three Jupiters, but money was not available.

Mr. Foord: I have listened with great interest to the Lecturer's statements with regard to his ideas on the installation of air-cooled engines and, in my opinion, he is doing important pioneer work in that direction. One of the points which appeal to me as being of the utmost importance is the greater measure of control by the engine designer of such features of the installation as are necessary for the proper functioning of the engine itself. This has been very well brought out by the Lecturer in the particular cases of the exhaust manifolds and the oil coolers, both of which have an important effect on the satisfactory running of the engine in service.

There is one point which always appeals to me as being very vague and that is the absolute value of the head resistance of the air-cooled and water-cooled types of aero engines. In this connection the Chairman has given a particularly interesting comparison. An argument generally advanced against the air-cooled

FIG. 26.
Suggested cowling scheme for Jupiter high-speed machine.

radial type of engine is that its greater head resistance is detrimental, especially for particular types of machines, such as the single-seater fighter type; but, generally, how much this matters from the actual horse-power point of view, is very difficult to arrive at and it seems to me that there should be considerable work carried out on this question in order to get down to bedrock. I mention this question of head resistance because of the interesting work which the Lecturer is carrying out in connection with the cowling of air-cooled radial engines in order to reduce the head resistance to a minimum.

With regard to oil cooling, this is of general importance to all types of engines, but more particularly so in the case of air-cooled, as on the average the air-cooled engine has higher oil return temperatures than the water-cooled. This is brought out by the fact that machines have recently been flying with return oil temperatures from the engine of about 110° Centigrade. The work carried out by Mr. Fedden on the tube type of oil cooler is very successful as far as it goes, but there is much more to be done in this respect.

With reference to the Lecturer's remarks regarding coolers installed in the oil tanks, experience in the past in this direction has not been very happy, as in certain types of installations the maximum cooling effect that could be got is of the order of about 5° Centigrade, whereas what is actually required is more like 30° Centigrade. In addition, the oil tanks are installed behind the fireproof bulkhead and that is inclined to render the problem more difficult.

The Lecturer states that provided the oil is cooled on return from the engine, the high temperatures experienced in the engine have no detrimental effect on the properties of the oil itself. I should like to submit that this is not the case, as constant exposure to high temperatures with the oils generally in use must of a necessity have a detrimental effect on the properties of the oil and thus shorten its useful life.

In connection with this question of lubrication, there is another point which appeals to me as being important, namely, satisfactory oil cleaning, in order to reduce the wear on the engine bearings, caused by constant circulation of dirty oil and thus lengthen life between overhauls. A certain amount of attention has been directed to this problem by engine designers, but from the general installation point of view there is a large field for a lightweight oil cleaner, possibly of the centrifugal type.

The Lecturer does not mention the engine starting problem, but this good old annual is still with us and, despite the good work which the gas starter is doing in many types of machines, the extra weight involved in such an installation is excessive, especially in the case of single-seater amphibians. There is a great opening for a small hand operated type of starter, which can be controlled by the pilot from the cockpit.

Another feature from the installation point of view which seems to give a fair amount of trouble, especially in the case of high altitude machines, is the wind driven petrol pump. It is considered preferable in all cases to make this an engine driven pump, and work in this direction is proceeding.

In conclusion, I should like to congratulate the Lecturer on his useful paper, which certainly draws attention to numerous features which are of the utmost importance from the installation point of view.

Wing Commander G. B. HYNES: One of the difficulties I have in entering the discussion is that if one ranged over the whole field of air-cooled radial engines, too much time would be occupied. I therefore propose to confine my remarks to the points raised by the Author in his paper. It is a very useful summing up of the position and not unduly optimistic in placing the case too strongly for the air-cooled radial.

Mr. Foord touched on what is the actual importance of drag to weight. It is very difficult to find any formula that will answer this question in one sentence. It is like one of those questions to which it is impossible to simply answer "yes" or "no" without any qualification. So much depends on the class of machine in which the engine is installed. On a high-speed machine the relative importance of drag to weight is large, something say of the order of 20 to 1, or 1 lb. of drag=20 lbs. weight; that is, drag would be more important than weight in some classes of machines than others. There is really very little data on this subject and one would like to know how to compare drag with weight on a slow, medium and fast machine. When we have more idea of what it actually represents it will give one a better opportunity of assessing its value.

The air-cooled radial is very short and this is for a very definite reason. If you lengthen the airscrew shaft there is the danger of lowering the synchronous speed at which resonant torsional vibration may occur, with the resultant risk of fracture of the shaft. This short nose of course is an obstacle to getting a fine entry for the engine. The Author is, however, considering how the nose can be lengthened, which disposes of one of the points to which I intended to refer. In high-speed machines they must have a fine nose, and I feel that there are several methods by which this could be achieved which have not yet been explored.

With reference to the exhaust system, I cannot agree with the statement that there is less risk of fire with a properly designed exhaust system than with stub pipes. If the exhaust system is very carefully designed and tested, I would say the risk is perhaps no greater. Otherwise any form of exhaust collector does usually add a very definite risk to petrol-engined machines. It would not exist to the same extent with heavy oil engines.

In paragraph 6—the lubricating system—there is a point I should like to draw attention to. I quite agree that it is accepted practice at present that the maximum oil circulation is desirable, but at the same time I am not sure that that does not require reconsideration in the light of experience we have had in other directions. It is bound up with the question of oil coolers. The figures given of the Author's oil coolers are most promising. I hope we may have some of them and get good results, but I am very doubtful. We have done a lot of work at Farnborough on oil cooling and it is very difficult to get oil to give up heat. All oil coolers at present, unless they are of gigantic size and weight, are extremely inefficient. The specific heat of oil is comparatively low, but once it picks up heat it retains it most stubbornly. We have not yet tested coolers of the Bristol type, but all we have tried have been extraordinarily disappointing up to date. It is a curious thing that the more promising they appear on paper the worse they seem in practice. The great difficulty seems to be that if you use a very cold medium for cooling you get a viscous layer of oil on the surface of the cooling walls and that acts as an excellent insulator. This is borne out by work that has been done at the Air Ministry Laboratory. I hope, however, that Mr. Fedden's figures will turn out true.

How this is related to the question of maximum oil circulation possible, is that if the oil is very difficult to cool, you have to have very large oil coolers to deal with large quantities of hot oil. As it is desirable to keep oil coolers as small as possible, that means the minimum oil circulation and not the maximum should be aimed at. I think we ought to study the minimum circulation necessary. The friction heat generated in the bearings and other moving parts can be arrived at quite easily and the oil required to cool them can be computed; over and above this, the less oil cooling of other parts that can be done the better. We have now one case of a water-cooled engine where the heat picked up by the oil is many times greater than that required to cool the bearings, etc., alone, and then you are faced with the problem of getting all this hot oil to give up its heat. It seems to me very significant that one of the most reliable engines in service now

circulates only 18 gallons of oil an hour, whereas another of half the power and no more reliable, circulates 450 gallons an hour. That is an enormous discrepancy and I think it is well worth trying to find out what are the real merits of the two schemes producing equal results in practice.

In the case of the water-cooled engine, the Air Ministry call for a definite rate of circulation of water per b.h.p. for the quite definite purpose of dealing with the heat given to the water jackets of the engine. In the case of oil, that problem never seems to have been examined, and I submit that there is a case for considering the advantages of a minimum and not a maximum rate of oil circulation, and perhaps even specifying a maximum permissible rate.

The point I wish to make is, that owing to the low specific heat of oil and difficulty of cooling it, oil cooling of parts other than bearings and moving parts must be inefficient, and is therefore undesirable, and reliance on it should be avoided as much as possible. As I see it at present, it would appear probable that the final exit temperatures of the oil will not be so greatly different, whether the rate of oil circulation is low or high (that is high in relation to the rates now generally used), and consequently the high rate of circulation will have the disadvantage of having merely and quite unnecessarily collected a quantity of stray waste heat without doing any real good. One might even go further and suggest that if extremely high rates of circulation are employed deliberately to contribute to the general dissipation of heat, that this could be regarded as a definitely detrimental feature in the design.

Referring to the paragraph on the carburation of radial engines, I should like to know how the temperatures in Table V. were measured and where, in the induction system, the figures were obtained. At Farnborough we have found that to obtain reliable and consistent measurements of the temperatures of a mixture of petrol and air is very difficult, and to place too much reliance on them may be very misleading. In the mixture as supplied to the engine, there is free petrol in the liquid state going through the induction pipe, and in consequence of the effects produced by the latent heat of vapourisation of this liquid, the figures obtained can be most unreliable and variable.

The figures given in Table V. for the rise in temperature of the mixture in the induction pipe are extremely interesting, but I think in this case the mixture must be collecting a very considerable amount of heat from such parts as the crankcase, etc., in addition to the heating obtained from the exhaust and oil heating and warm air intake.

In some experiments carried out at the R.A.E. some time ago, where the ingoing air was pre-heated 30°C. above the surrounding atmospheric temperature before carburation, the resultant mixture temperature after passing through the carburettor was only 1°C. above the atmospheric temperature. When the pre-heating was increased to 60°C. the increase in the mixture temperature was only 2° or 3°C. The small difference in the mixture temperatures for the great difference in the temperatures of the ingoing air to the carburettor is probably explained by the greater quantity of petrol completely vapourised by the hotter air and shows the effect of the latent heat of vapourisation.

On the question of the value to carburation of oil jacketting, the point arises which I mentioned before. The very cold mixture above the choke passing through an oil-jacketted pipe seems likely to cause enough oil to adhere to the walls of the pipe to make it act as an insulator and the heating effect will be small. On the figures as shown there is a difference of only one degree.

The oil jacket may, however, have a use in just preventing the carburettor freezing up on an air-cooled radial engine in gliding flight at very low temperatures.

I quite agree with the Author on the subject of altitude control. I prefer jet to vacuum control. Where vacuum control is used the shape of the air intakes

and their position have an enormous effect on the tuning of the engine. With vacuum control the engine has generally to be retuned when it gets into the machine and the shape and position of the air intakes is altered. This is not the case with jet control and normally the bench tuning is not greatly affected by the shape of the air intakes.

The fire risks I have mentioned, I may say in reply to General Brancker's inquiry, are in case of a crash.

Mr. HAROLD BOLAS said: The fact that a very large circulation of oil and big oil cooler is required appears to suggest that a good deal of the engine cooling is carried out by this means, instead of directly by the air, which is not as it should be. Some time ago I carried out a cowling experiment on a Lucifer engine which gave astonishingly good results, although it is admitted that only one test was taken and the results cannot be taken as conclusive without further work. In this case each cylinder was fitted with a helmet which faired the back of the cylinder only, and was arranged to be a tight fit along the fins on the centre line of the cylinder. The front of each cylinder was thus directly cooled by contact with the air flow.

To cool the backs of the cylinders the air was admitted through the central hole in the exhaust ring over the crank chamber and was then caused to flow out more or less radially over the backs of the cylinders, finally emerging through holes in the backs of the cylinder helmets. The maximum cylinder temperature registered at the rear sparking plug did not exceed 140°C., although the test was carried out on a hot summer day. Tests in winter indicated that the engine was being kept too cool. As I said before, these results were isolated cases, and there was not time to carry out any further experiments. However, this particular type of cowling may be worthy of further consideration, and—apart from manufacturing difficulties in making the cylinders—the results would suggest that the fins on the backs of the cylinders should preferably be arranged in a radial fashion instead of circumferentially around the cylinders.

Colonel BRISTOW: The question of drag and its relation to the installation of the engine is, in my opinion, one of the most important factors in this subject. It is unfortunate that so little real work has been carried out in this country on the relative resistances of different types of engines when fitted to machines specially designed for them. What little work that has been carried out has in my opinion produced somewhat misleading results unfavourable to large engines.

At Göttingen recently some tests were carried out on a model equipped with two air-cooled radial engines and the first results showed the machine to have no better performance than when fitted with two water-cooled engines weighing together about 900/1,000 lbs. more.

The results were disbelieved and fresh engine models were made, four times the size of the first, and the new figures were altogether different and much more in favour of the radial engine.

In practice some rather striking results have been obtained. The first multi-engined aeroplane to be fitted with large air-cooled engines since the war was a Handley-Page 0/400 passenger machine on the London-Paris service. The engines, which were Jupiter MK.3, displaced Rolls Eagle 8 engines of about the same h.p., if anything the Eagles gave a little more output and had geared propellers running at a much more efficient speed. In spite of this the machine with the Jupiter engines was 10 miles per hour faster and had a much better climb. These results completely upset all expert expectations.

It must also be remembered when on this question of drag, that it is not sufficient to compare the figures of two different engines except when taken with the whole machine which should be specially designed for each type of engine.

For example, an air-cooled engine of about 450 h.p. will weigh about 450 to 500 lbs. less than a corresponding water-cooled engine complete with cooling system.

If, therefore, the two machines fitted with these engines are to work at the same surface loading, say 10 lbs. per sq. ft., there will be 45/50 sq. ft. more wing surface required in the machine with the water-cooled engine. This is only one factor that arises, there are others which will doubtless also occur to you. all of which emphasise the point that I wish to make, namely, that for engines differing widely in shape and weight even though of similar output, it is essential to consider the drag of the whole machine and not of the engine only. This has been well recognised in France where great attention has been paid to the question of reducing the drag of machines fitted with air-cooled engines, with the result that many more types of machine are fitted with Jupiter engines than in this country and from which very much higher speeds have been obtained. For a race, for example, such as the Schneider Cup, where an engine and machine are required light in weight and capable of being turned round corners at very high speeds, a lightweight radial engine has great advantages, and with its aid it should be possible to design machines 33⅓ per cent. less in total weight than those with a large water-cooled engine.

The overall weight-per-h.p. factor and the manœuvrability will be all in favour of the lighter engine, and if attention is concentrated upon the problem of suitably fairing the air-cooled engine we may yet see a machine of this class emerge triumphantly from the eliminating trials of 1926.

Mr. BULMAN: I think that not the least valuable part of this most useful and practical paper is the emphasis which the Author has given throughout it for the urgent need of a greater measure of co-operation between the engine and aircraft designers. Too often they seem to regard their duties as being entirely separate and self-contained, whereas fundamentally the aims of both of them are really one, to produce an efficient and reliable aeroplane. The need for complete co-operation has always seemed to me to be particularly necessary in respect of the radial engine, although one feels after what has been said to-night that we may have been a little led astray in our views, regarding the relative head resistance of the radial type, by the fact, for which zoologists vouch, that the starfish does not seek to make progress in a forward direction perpendicular to its own plane.

On the question of oil cooling, apart from the obvious desirability of maintaining the oil at a reasonable temperature, it was brought home to me forcibly the other day, that certain types of oil, some of which are normally used in aero engines, are apt if their temperature has once been raised above a certain point, not in itself high, to develop when mixed with only a minute quantity of water, the most intense corrosion and rusting, indeed, to an astonishing degree. The air-cooled engine, of course, is subject no less than the water-cooled type to the effects of internal condensation which would provide sufficient water for this action to start.

In respect of altitude control, the jet control from the point of view of manufacture, inspection and maintenance is, I think, far in advance of the vacuum system, while in addition it is less likely to upset the carburation of an engine as tuned up on the test bed when the engine is installed in a machine and in different types of machine.

I have heard that in France the Jupiter engine is commonly found to maintain its speed of revolution at a height uniformly in excess of what is normal here. If this is a fact it would seem attributable only to installation effects, and I should like Mr. Fedden's views, firstly, as to whether the report is true, and secondly, his suggestions as to the real causes of the difference.

Mr. BISHOP: It is particularly interesting to find the engine designer extending his considerations towards problems of installation of the engine into the aircraft. Hitherto, he has usually confined his attention to the engine itself with the result that the complete aircraft has not always been successful, owing to either the installation system not suiting the engine or vice versa. There is no doubt that the design of the complete power unit installation should receive the attention of both the engine and aircraft designer so that both of their aspects are given their relative degree of consideration. The Author's reference to the necessity of adequate bearing areas being provided in joints of engine mountings for air-cooled engines raises a feature which aircraft designers have not given due weight to in the past, not only as regards engine mountings, but generally throughout the structure. Experience in the maintenance of aircraft has repeatedly shown that this deficiency has been responsible for high maintenance costs, in that extensive replacements of parts have been necessitated merely on account of excessive wear being found at joints. Further, rapid wear in such cases results in vibration and thereby causes more rapid deterioration to the whole of the rest of the structure. Increased bearing areas at joints do not necessarily incur additional weight, but even should this be found to be unavoidable, the relative increase in the life of the aircraft should outweigh the insignificant effect on performance.

Major MAYO: First of all I should like to thank the Lecturer for his valuable paper. We all know of his ability as an air-cooled engine designer, and of the many achievements of his engines in all classes of aeroplane.

With regard to head resistance, there is not much left to say, but I should like to ask whether Mr. Fedden has had any further tests done on models in continuation of the tests that were done on the Westland Weasel with a Dragonfly engine. They were tested with the cylinders sticking out and afterwards with the cylinders cut off. It has always seemed to me that that test was a fallacious one, because there is practically no machine that has a perfect streamline nose and the comparison was therefore unfair to the air-cooled engine.

It would be very useful to have a series of tests done to find out how much of the cylinders need be exposed. There appears to be a wide divergence in this respect in various air-cooled engine installations.

With regard to the D.H.50, the Chairman has mentioned that this machine gives the same performance as it should give on paper, assuming that the resistance is no worse than with the Puma, but I think that we ought to make quite sure that there is no other factor coming in. It appears that an air-cooled engine does not cause as much resistance as has been generally reckoned, but I think it must make some difference.

With regard to Colonel Bristow's remarks, I do not think that a comparison of the Handley-Page fitted with Rolls-Royce and Jupiter engines is quite a fair comparison. In that machine the Rolls engines were left without cowling and with no attempt at streamlining, so that the comparison is perhaps not quite fair to the water-cooled engine. I am not, however, trying to make out a case against the air-cooled engine, because in my opinion it offers great opportunities for progress, but this question of resistance is a serious one, and I look forward to the day when the cylinders will be helmeted.

We have heard a good deal about oil temperatures but not much about actual cylinder temperatures. It would seem to be a great advantage to have the cylinder temperature under control, because if the engine is not too hot when flying low down in the tropics it must surely be too cold when flying in England. I should like to have some idea of the range of cylinder temperatures Mr. Fedden considers permissible. Helmets giving control of the cooling would enable the engine to be used most efficiently in all climatic conditions.

I do not think the question of reduction gears for air-cooled engines has been mentioned. If we could have an air-cooled engine with a reduction gear it would be of great assistance for commercial purposes and for heavy bombing machines. It would make a great difference to the take off and climb. I hope Mr. Fedden will tell us whether he is developing a geared engine and whether it would mean a serious addition of weight in the engine and mounting. A reduction gear might improve the shape of the nose and, on the other hand, it might perhaps interfere with the cooling.

With regard to the question of racing, Colonel Bristow suggested that we might win the Schneider Cup if our next year's machines were fitted with air-cooled engines. The air-cooled engine is of immense value for commercial work and for many classes of military work, but for racing the difficulty is to find an engine which is sufficiently powerful. For next year we want a machine with an engine giving 1,000 or nearly 1,000 h.p. Is it possible to produce a suitable air-cooled engine of this power? In the case of the American machines with water-cooled engines the size of fuselage has been reduced to the minimum necessary to contain the pilot. It would be very interesting to know what maximum horse-power for an air-cooled engine Mr. Fedden has in mind for the near future?

Mr. A. P. FOLLAND (*communicated*): In the introduction Mr. Fedden mentions advance made with the air-cooled radial and its relative merits to the water-cooled engine. I do not think there is any doubt as to its advance in relation to the water-cooled engine with the exception to using the air-cooled radial as a pusher. This to me seems to be one of the biggest drawbacks with the air-cooled radial types, although at the same time I think that this might be overcome in the near future, and suggest that a great deal more experimental work should be done to enable the air-cooled radial to compare absolutely with the water-cooled types.

In Table No. 2 Mr. Fedden has tabulated a very useful little table comparing the weights of engine mountings and cowlings. Up to the present, in actual use, the air-cooled radial has not been cowled in sufficiently to give the best results aerodynamically, although at the same time experiments have been done with helmeting. It appears to me that when the cowling on this engine has been satisfactorily carried out, allowing for the use of helmets, which will be necessary in the near future to control the air-cooling for high altitude fighting, the weight must necessarily be increased to double the present weights of cowling now being used on the standard scout machine. This will bring up the weights of cowling to somewhere nearer that of the water-cooled types.

With regard to engine mounting, I do not think it at all possible to standardise the engine mounting for some long time to come as the aircraft designers all have different ideas as to the method of fixing the engine and to standardise the mounting would retard the designers on their individual efforts.

On the question of the oil cooler, there certainly seems to be room for improvement of the external oil cooler, which adds unnecessary drag to the high-speed fighting machine. I should consider that this could be satisfactorily arranged, as already suggested, by running the oil through an induction system in the form of a heater box. This has already been done satisfactorily on other air-cooled radial engines.

Mr. Fedden also mentions below Table No. 5 his opinion that flexible connections on petrol systems are necessary. I, personally, agree with Mr. Fedden and think that this is absolutely necessary to have some form of flexible pipe or connection between pipes from the machine to the engine, especially in the small machines, as these pipes are short and stubby and liable to fracture, and at the same time they are subject to distinct movements between engine and aeroplane.

Under the subject of cowling, Mr. Fedden mentions the necessity of making a substantial fixing as a great deal of trouble has been experienced in the past with fractures and cracking generally. I think that consideration in this direction should be more carefully considered and a great deal of fracturing could be eliminated if care was taken to have the cowling either directly supported from the engine itself or, alternatively, directly supported from the aeroplane structure. There have been cases where cowling is partially supported by the engine and partly by the structure. This combination invariably introduces fractured cowling.

I was extremely pleased to note the possible new types of air-cooled engines. There is really little doubt that the air-cooled engine can hold its own against water-cooled engines manufactured in this country, a big advantage being that one can obtain a smaller aeroplane with a low structure weight and this permits of a good manœuvrability at a fighting altitude and also excellent climb; the little which might be lost at the present moment on resistance adequately makes up for the excellent climb and manœuvrability.

In conclusion, I should like to congratulate Mr. Fedden on his excellent paper, which should be of great use to the aircraft designer.

Colonel L. F. R. FELL (*communicated*): I have read Mr. Fedden's paper with the greatest interest as, in my opinion, it brought to light certain problems which it was very necessary should be dealt with without delay. I agree with the two paragraphs of the paper regarding the future possibilities of the air-cooled radial and consider that the limit of development of this type of engine had not nearly been reached.

With regard to engine mountings, section marked (3), I think that far too little attention was paid by aircraft designers to the possibility of resonance in engine mountings. It was frequently the case that a certain type of engine would be stated to vibrate badly at certain speeds in certain machines. In such circumstances it was usually the practice to state that the engine had a bad period at these speeds, whereas in reality the source of the trouble lay in the fact that a state of resonance existed in some portion of the engine mounting at the speed complained of. It was, of course, impossible to ensure that that trouble would not manifest itself however carefully the engine mounting was designed in the first place, and whether or no this condition was present could only be determined by an inspection of the mounting with the engine running under varying speeds and loads. At the present time this was not done as the engine mounting was covered in before the engine was run up. I think that a mounting in which fairly long unsupported tubes were used was very likely to give trouble due to this cause. This had been experienced on more than one occasion with water-cooled engines.

On page 3 the Author referred to the exhaust ring which had been produced by him, and I consider that great credit is due to Mr. Fedden for his perseverance in satisfactorily overcoming this most difficult problem.

Under lubrication system, the Author referred to the cooling of lubricating oil. It seemed somewhat astonishing that so little attention had been bestowed on this subject in so far as scientific research and experiments were concerned, when it is considered how much work had been done on radiators for water-cooled engines. The oil cooler was almost as important a device to the air-cooled engine as the water radiator was to the water-cooled engine. On the water-cooled engine the device known as the oil temperature regulator had been used with some success; though this device was originally produced in England it had not found much favour, but had been adopted in America with a certain amount of success. On the air-cooled engine it was obvious that air must be used for cooling the oil and some form of cooler which could be affected by the slipstream must be fitted. The suggestion to use the hot oil to pre-heat the ingoing gases, thereby extracting the necessary amount of heat from the oil, was impracticable for two reasons:

1. The amount of surface necessary in order to take full advantage of the volume of air going into the engine would necessitate employing some form of radiator in the air intake with consequent obstruction to air flow.
2. The quantity of air used by the engine was far too small to extract the quantity of heat as given in Table No. III., without increasing the ingoing temperature of the air to such an extent as to completely upset the performance of the engine.

The method of fitting an oil jacket to an induction pipe had very little effect with regard to reducing the oil temperature or increasing the temperature of the incoming air, for the reason that an insulating layer of cold oil formed on the outside of the induction pipe, allowing the hot oil to pass over this layer, thereby destroying the efficiency of the surface.

With regard to the tandem system of installing radial engines, it seemed to him that this was the only way in which an air-cooled engine could be used as a pusher. From the purely engine point of view this method of mounting appeared highly desirable provided it had no great aerodynamic disadvantages.

Mr. TINSON (*communicated*): (1) With regard to engine mountings, it is rather unfortunate if the carburettors or supercharger at the rear project downwards in such a way that cross-bracing of the underside rectangle of the mounting cannot be achieved, for to gain accessibility there should be a reasonable gap between the rear of the engine and the fireproof bulkhead, and in such case the mounting is long enough to require this cross-bracing for rigidity.

If, on the other hand, the cross-bracing in this plane is below the carburettors, the latter may be difficult to drop when it is required to get them off the engine or to gain access to the jets, etc., for tuning.

It is doubtful if an engine mounting which is strong enough to pass Air Ministry requrements as to factors will deflect much under working conditions, provided that one can brace it on all four sides. Since the boundary enclosing the forward end of the mounting, level with the back of the crankcase, must approach to a circular form to give even cooling on all cylinders when cowled in, and since bracing in the bottom plane is admitted to be at any rate a desirable, if not essential, feature, the importance of restricting the width of any downwardly projecting part is evident.

(2) The weight of installation per b.h.p. in Table I. is evidently based on 450 b.h.p., whilst the engine mounting and cowling weights per b.h.p. in Table II. are based on a figure of 400 h.p. For strict comparison in the case of Table I., should not the nominal h.p. for the radial-engined machine be as stated in Table II?

Also, what does the figure for installation comprise in the two cases, air and water-cooled? Presumably the radiator (water or oil) and exhaust systems are included in each case.

(3) It is not apparent how the polar moment of inertia of the engine affects the design of engine mounting. The usual factors demanded on this presumably cover, from experience, the torque variation and other forces present, and possibly the polar moment is only of use as a means of comparing engines in their effect on the behaviour of machines in certain manœuvres.

If the polar moment be considered as a measure of the ability of the engine to absorb the energy of its kick internally, one is bound to face the fact that the engine components are made as light as possible, and therefore whatever the polar moment may be, it cannot be helped.

Similarly, no more weight is put into the mounting than is found necessary to do the job and meet required factors, so that one can hardly see how a knowledge of the polar moment can be advantageously applied.

(4) With regard to cowling, the difficulty in the front part comprising the panels between cylinders is that these must be offered up and removed in a direction radial to the centre line of the engine, in order to get them on and off the fasteners. The fasteners themselves, being radial projections, require a wider slot to be made in the cowl panel than would be the case if the panel were on the flat, owing to the greater width between the tops of an adjacent pair. The slot, however, must not be unduly large if the panel is to be a firm job, and the panel may have to be coaxed on and off in consequence. In addition, when off the fastenings, it has to be wriggled out, for it cannot be lifted clear owing to the projection of the sparking plugs, etc. The result is rapid deterioration of the panel.

In view of the infrequent removal of any cowling ahead of the cylinder centre line, perhaps an aluminium extension to the skirt of the exhaust ring, to fair in as far back as the cylinder centre line, would alleviate the difficulty, though the nuisance of radial fasteners behind would still remain.

(5) The effect of wide ranges of temperature on carburation is without doubt a difficult thing to combat. I think, however, that there must be a misprint in my advance copy of the lecture, $+6°C.$ to $-49°C.$ (37,000 feet odd) in ten minutes being a rate of climb we are never likely to achieve.

May I ask if there is any serious objection to oil jacketting the induction pipes and carburettor in a similar manner to that adopted in water-cooled engines?

One of the difficulties to be expected with an air-cooled engine would seem to be that on shutting down to glide from an appreciable height, the heat supply to the carburettors provided by the exhaust ceases to function, whilst in the water-cooled case the body of hot water available will retain its temperature for some time and tend to maintain the carburettor in a better condition for rapid acceleration at the end of the glide, *i.e.*, obviate any tendency to choke through imperfect vaporisation. I am not aware if the difficulty I suggest is actually encountered in practice.

Colonel SEMPILL (*communicated*): I should like to ask the Lecturer as to whether he is aware of the principal reasons that have caused Imperial Airways to standardise, at least for the moment, on the air-cooled engine?

The air-cooled engine in the seaplane has regrettably received very little attention in this country, and it would be interesting to hear as to what the experiences have been of those Jupiter engines fitted in foreign sea-going aircraft.

Of particular interest is the tandem arrangement in the Dornier Wal, as this provides a pusher with attendant difficulties in cooling.

Air-cooled engines it seems should have a great future in seaplanes, particularly when the cooling difficulties have been explored and overcome. The ease of getting under way petrols of flying boats ordinarily kept at moorings, particularly in cold weather, should be considerably greater than with the water-cooled engines.

The emphasis placed by the Lecturer on the growing necessity for the control of cooling raises a point that I suggest has received far too little attention. Controlling arrangements for maintaining constant temperature are surely going to be demanded in the very near future and in certain services more particularly than in others. The cooling of oil, as the Lecturer has pointed out, requires a considerable amount of investigation, but I should have thought that the method of incorporating the cooler in the air intake is not particularly desirable, owing to the tendency towards decreasing the volumetric efficiency of the engine.

The pending improvements in induction systems will tend to allow the taking in of the coldest possible mixture which will have the effect of increasing efficiency and which will at the same time not be prone to suffer from the disadvantages that arise to-day.

Sir SEFTON BRANCKER, in passing a vote of thanks, said: I am extremely glad to see an engine designer facing this problem of installation. It is a problem that has always fallen between two stools; but as the engine designer is always blamed if an accident is due to the failure of the engine installation, he may as well take the responsibility of attending to the installation.

Two very evident facts stand out as a result of this lecture; we need a great deal more research on the question of drag and head resistance, and on oil cooling.

I am afraid that the discussion veered rather from the question of installation and on to the qualities of the air-cooled engine itself; but I hoped that perhaps this would rouse some of the protagonists of the water-cooled engine to state their case. From the absence of criticism, I judge that you agree with me on the great value of the air-cooled engine.

I have always believed that it was logically right that an engine operating in the air should be air-cooled. Both we and the nation at large owe Mr. Fedden a great debt of gratitude for producing this remarkable series of engines, the Jupiter, the Lucifer and the Cherub; and I congratulate him heartily on his paper, which is a really valuable contribution to the practical progress of aviation.

REPLY.

Mr. FEDDEN, in reply to the discussion, said: I would prefer not to attempt to answer the written communications now, but will devote the remaining time to answering as far as possible those points raised in the discussion.

I cannot understand an aeroplane designer saying that he can find no use for the polar mass moment of inertia of an engine; this, I would submit, is needed in order to estimate:

1. The amount of damping out of the engine torque variation.
2. The effect of any possible synchronisation of the natural torsional period of the engine on its mounting, with the engine explosion period.

I have had experience of one or two engine mountings which were quite satisfactory at full throttle, but as the engine was run up, a serious synchronous vibration developed in the engine mounting. Every engine has a natural period, and it is the object of the engine designer to keep this period as far away from the running speed as possible. By using the polar mass moment of inertia of the engine together with the other tabulated data provided with engines, I am of the opinion that the aeroplane designer should be able to obviate these difficulties.

The Chairman has asked the minimum time necessary to remove a "Jupiter" engine. The only actually timed example which comes to my mind is somewhat a special one, and might be termed a stunt, but four trained men have actually replaced a "Jupiter" engine in $3\frac{3}{4}$ hours. I am not prepared to say that this could be repeated day in and day out—a great deal depends upon the installation—but there is no doubt whatsoever that an air-cooled radial, if properly installed, could be changed while the radiator and cowling of many water-cooled installations are being removed.

I was extremely interested and encouraged to hear the frank remarks of two speakers on their views of how an engine maker should stand in relation to aircraft engine installation; I have not dared to speak so plainly in my paper, or to claim for the engine maker nearly as much as has been suggested this evening should be his province, but I do feel strongly that co-operation is absolutely necessary, and that we can greatly improve and simplify installation by getting together on this important subject.

I agree generally with Mr. Foord's views about oil coolers. The coolers I have described in my paper I do not suggest are by any means final—they cover a range which we have found satisfactory up to the present—I am quite sure they can be improved.

I also agree with Mr. Foord's remarks on oil centrifuging. A " Jupiter " IV. engine was specially constructed with an oil centrifuging device integral with the crankcase, the engine was run normally for 100 hours, and I was very surprised on opening up the centrifuger to find the quantity of hard deposit which had collected during this period of running. We had this deposit analysed, and found that an appreciable proportion of it consisted of various metals; the deposit was much too fine to be trapped by any strainer. After careful consideration, I decided to leave the centrifuging device out of the new " Jupiter " 1926 production because the extra weight and complication could not be faced for all types, and the introduction of the centrifuger would introduce another type. I am quite convinced, however, that from the tests we have made a centrifuger would be a valuable addition to a commercial aircraft installation, and I would suggest that a wind-driven type should be tried out on a commercial machine, and see what would be the difference in the life of the bearings.

Oil coolers have proved satisfactory in the tank, providing the speed and performance of the machine is such that the oil is not up to maximum temperatures. Fig. 12 shows an integral tank oil cooler which has been used successfully in France; this machine is a thick wing monoplane type with a good gap between the fuselage and the wing, and it is easy to incorporate such a cooler in this type of machine.

I was very interested indeed in Colonel Hynes' remarks on the value of drag/weight ratio for air-cooled engines. I quite agree that it is most important that the engine maker should have definite information on this subject. There is a considerable amount of laboratory work to be done in this respect; Captain Barnwell is at the present time investigating the drag question on behalf of the Bristol Company.

Colonel Hynes remarked upon the shortness of the air-cooled radial and consequent blunt entry. The schemes I have suggested for a new type of radial installation show the crankshaft considerably lengthened.

In earlier days, engine designers were very loath to lengthen the crankshaft owing to the fact that this would bring the synchronous speed of the engine nearer the running speed, but I do not fear this problem now, as with the help of some very interesting investigations made at the R.A.E., we can with certainty design crankshafts for radial engines within reasonable limits so that we can rely definitely upon keeping away from this danger.

I am quite sure that much can be done by lengthening the nose, in co-operation with the aircraft designer, to generally lower the drag of the radial installation.

The table of figures of induction system temperatures I admit may not be accurate, but are comparative; the results were obtained by means of a special instrument made for us by the Cambridge Scientific Instrument Company. The air intake temperatures were taken at the end of the common air intake pipe, which is standard on the " Jupiter " IV. engine.

I quite agree with Colonel Hynes that a series of tests to show the minimum amount of oil necessary in circulation on an engine would be valuable, and I am at the present time making such a series of tests in the " Jupiter " engine.

In connection with this matter, earlier in the discussion Mr. Bolas remarked that the " Lucifer " engine did not require an oil cooler. I attribute this partly to the low P.V. constant of the big end bearing on this engine, but more to the low oil circulation, which is only twenty gallons an hour.

The point raised by Mr. Bolas in regard to the cylinder finning is extremely interesting, and one upon which there is a very wide field open for exploration. I quite agree that in theory we should have a different type of finning on every engine installation, according to the duties and functions of the machine, just as we have different sizes and types of radiator on water-cooled installations, but this is impossible owing to the varying types of cylinders. I think the only solution is variable cooling.

In reply to Major Bulman's remarks, I am at the present time endeavouring to ascertain why French-made "Jupiter" engines are stated to give such very good performance at altitude; I believe these results are due to

1. The very low specific gravity petrol used in France.
2. High compression ratio.
3. Propeller design.
4. French machines on the whole are "cleaned up" better.

"Jupiter" engines in France used on scouts are for the main part fitted with 6.5 compression ratio; these engines have, of course, been type tested on the ground at this compression ratio. I would like Major Bulman's staff to see these engines running. As a matter of fact they function extraordinarily well, but I am afraid the detonation on most of the French high performance altitude engines would not satisfy the A.I.D.

With reference to Major Mayo's remarks on cylinder temperatures, it is one of the great points in favour of the air-cooled radial engine that one has a much greater range over which the engine will function satisfactorily, as compared with its water-cooled competitor. An air-cooled cylinder will maintain full power if the mean temperature of the fins does not exceed 175°C. On the other hand, if the mean temperature of the cooling surfaces of a radiator exceeds 80°C., evaporation losses become considerable. Hence, in hot climates, where the air temperature may vary from 0°C. to 45°C., the temperature difference available for cooling may diminish 50 per cent. in the case of the air-cooled cylinder, whilst the diminution is only 25 per cent. in the case of the air-cooled cylinder. Whilst this difference will do no harm to the air-cooled cylinder, the water will be boiled away rapidly in the radiator of the water-cooled engine. When these conditions occur with great changes of altitude, the air-cooled engine is even still more at an advantage. Taking the tests that have already been made in very hot climates, including one 115 hours' endurance test without dismantling in Mesopotamia, the results with the "Jupiter" engine have been extraordinarily good.

In answer to Major Mayo's query as to the feasibility of gearing the "Jupiter," this is entirely a question of money. I realise the importance of gearing this engine for certain installations, and, as I am sure, the Chairman will bear me out when I say we have been considering how this problem could be met. I am quite sure that if the demand justified the expenditure, a satisfactory reduction gear could be produced. An experimental concentric epicyclic gear has already been made for the "Jupiter" engine and run satisfactorily, but there are certain modifications required; the additional weight is 100 lbs.

As regards the question of the possibility of using an air-cooled radial engine on racing machines, I dare not attempt to answer this question fully, as the discussion would more than fill one evening's debate. I would state, however, that although some considerable progress has been made in the design of air-cooled radial engines during the last few years, I do not think we have anything like approached finality, and that great reductions can still be made in weight and drag. The present "Jupiter" engine is 1.49 lbs. per b.h.p. I have no hesitation in saying that we shall be able to produce air-cooled radial engines at under 1 lb. per b.h.p. in the near future.

The Gourdou machine in 1923 obtained the European speed record and held it for over a year with a Series IV. "Jupiter" engine developing 450 b.h.p. maximum and 57in. overall diameter. In view of this performance I believe that those people who are so ready to condemn the radial on the question of drag would be surprised at the results possible with an installation on the lines I have shown in my last three slides, with an engine of nearly double the power used in the Gourdou.

1. *Mr. Folland.*

I agree that more experimental work must be carried out to enable the air-cooled radial to be used as a pusher. From the work the Bristol Company have already done in this respect, I can state that the results are quite promising, and I have no doubt that a successful pusher radial could be made, providing that we could get sufficient interest taken in the engine from the aeroplane side to justify the cost of the necessary experimental development.

With regard to paragraph No. 2, I agree that some form of helmeting will be required for air-cooled radials, in order to obtain satisfactory temperature control at very high altitudes, but I do not think the weight of this helmeted cowling will be as serious as Mr. Folland imagines; I believe we can make great improvements on our first attempts at helmets, and I do not think it ought to add more than 20 lbs. weight to the engine installation.

I entirely concur with the remarks of Mr. Folland contained in paragraph 6 on cowling.

2. *Colonel Fell.*

I have experienced exactly the problems described by Colonel Fell in his second paragraph, both on radial and in-line engines. The coincidence of natural periods is a very difficult problem for which to legislate, and the development of the polar mass moment of inertia of the engine was intended to help the aeroplane designer in this respect.

With regard to paragraphs 4, 5 and 6, dealing with preheating of the air intake gases, it is realised that oil is not a suitable medium for this purpose. The oil heater used on the "Jupiter" VI. triplex carburettors serves a useful purpose, in so much as just sufficient heat is extracted from it to prevent freezing round the diffuser.

I agree with Colonel Fell that the fitting of an oil jacket round the induction system has very little effect, and am of opinion that exhaust heating is the only practical solution.

3. *Mr. Tinson.*

In reply to No. 1, I admit that the disposition of accessories at the rear of a radial engine may not be ideal, but by suitable grouping the rear cover may be made quite a practical proposition from the mounting point of view, and the problem of suitably bracing the bottom bay has been successfully tackled by several aeroplane designers.

Data on comparative installation weights is very difficult to obtain. The figures for installation units in Table I. are as supplied by the manufacturers of the aeroplane, and include mounting, cowling, cooling gear, and tanks.

With regard to paragraph No. 3, I regret Mr. Tinson does not find the polar mass moment of inertia of the engine of any assistance to him in designing engine mountings; this is not the opinion held by certain well-known aeroplane designers who have expressed their appreciation of these figures, which were previously unobtainable.

In reply to paragraph 4, relating to cowling, I appreciate the difficulties involved in giving satisfaction to both the engine designer and the maintenance

engineer, but experience with all types of machines has convinced me that satisfaction in this respect can be given by the machine designer if he thinks it worth while.

With reference to paragraph 5, Mr. Tinson must be referring to the Air Ministry Standard Temperature Altitude Chart. Unfortunately, our climate is a law unto itself. The wide range of temperatures referred to by me were actually obtained during a climb of approximately 20,000 feet during the past winter.

These low temperatures certainly call for additional heat supply to the induction system; the objection to oil-jacketting the induction pipes is that the extra complications are not justified by results. Although the air-cooled radial has not such a big heat reserve as the water-cooled engine, it should be remembered that it attains a normal running temperature more rapidly, a small throttle opening providing ample heat with a suitable installation.

4. *Reply to Letter from Mr. C. C. Walker to General Brancker.*

The first part of this letter deals with calculations of the relative speeds of the D.H.50 with Puma and Jaguar engines.

I do not agree with Mr. Walker that the drag of a radial engine is as serious as he thinks it to be, and the performances obtained with recent "Jupiter" installations are, I think, sufficient proof of this statement.

Mr. Walker states that the D.H.50 is an almost ideal case, because of the size of the body behind the engine. For general military purposes, I do not think it is possible to have a smaller body than that which can be easily accommodated behind the latest "Jupiter" engine. I also do not agree that it is impossible to build a really fast aeroplane round a radial engine. In 1923 the French Gourdou accomplished a speed of 226 miles an hour with the old type "Jupiter"; we are now producing engines with 12 per cent. less frontal area, an increase of 50 b.h.p., and 80 lbs. less weight.

I have tried to show in my paper that we have not by any means reached the limit in respect of reductions in drag, and I believe that by co-operation between the engine maker and the aeroplane designer a satisfactory high-speed machine can be made with an air-cooled radial.

In reply to Mr. Walker's remarks relating to the installation of a radial engine in a big cabin machine like the D.H.34, I would submit that it would be bad practice to have the radial engine close up in front of the large cabin; that with the lesser weight of the "Jupiter," as compared with a corresponding water-cooled engine, I think Mr. Walker would find that it would be necessary to prolong the nose of a machine such as the D.H.34, and that the engine could be mounted on a long tapering nose which would provide satisfactory cooling, and also good get-away for the slipstream from the propeller. On a similar type of installation of which I have had experience, the long tapering nose has been found the best solution, and gave a definite increase in performance.

5. *Colonel Sempill.*

In reply to Colonel Sempill, I believe that the single bank air-cooled radial has a very great future for commercial aircraft, and will, during the next few years, hold the field for this type of machine. The reason for these beliefs is, that an engine of this type has proved that it is at least as reliable as any water-cooled engine, that it is 30 per cent. lighter than a corresponding water-cooled engine, that its initial cost is much less, and that its maintenance and repair cost, both as regards spare parts and man-hours in overhaul, are far less than a corresponding powered water-cooled engine; further, that the air-cooled engine can operate in extremely cold and hot climates in a way that cannot be approached with the water-cooled engine.

With regard to Colonel Sempill's question on foreign seaplane installations on the Continent, very considerable success has been obtained with "Jupiter" installation, notably on the Farman Goliath twin-engined machine, the Caproni twin-engined machine, the Dornier Wal twin-engined machine, and the Hansa-Brandenburg single-engined machine.

I have recently had a report sent me from Morocco giving particulars of two squadrons on active service with "Jupiter" engines; these machines flew from Bizerta to their base, Mellia, a distance of 750 miles. For the last seven months these engines have been in continual service, and have flown an average of 130 hours without any trouble whatsoever. I am informed that the French Marine have never had anything like such remarkable service with this type of machine with a water-cooled engine, and are very satisfied indeed with the "Jupiter" installation.

I quite agree with Colonel Sempill that there is a great future for the air-cooled engine on seaplanes; in fact, the very low power-weight ratio and the ability to get off rapidly are so valuable for this type of machine that I think there is no doubt that air-cooled engines will be used in large numbers on seaplane construction in the future.

I also believe that large multi-engined seaplanes will find air-cooled engines very useful owing to the big saving in weight. There are two very interesting types of such machines nearing completion at the present time—one is a three-engined "Jupiter" seaplane, and one a five-engined "Jupiter" seaplane.

With reference to Colonel Sempill's remarks relating to the oil cooler incorporated in the latest type Bristol triplex carburettor, as I have endeavoured to point out, this should be termed a carburettor heater rather than an oil cooler; the oil will be cooled only a very few degrees by this method, but it is valuable in so much as it keeps the dew point from the diffusers, and consequent freezing.

I do not agree with Colonel Sempill's last remarks regarding the temperature of induction. Obviously greater charging efficiency will be obtained if cold air can be used, but from my experience of aero engine installations, this is impossible, except with supercharged engines. Preheating of the air is absolutely necessary.

CORRESPONDENCE

DEAR GENERAL BRANCKER,

D.H.50 J.

The speed of the D.H.50 J. to compare with the Puma engine version can be calculated by any usual method. The following, however, is a very simple approximate method.

In a machine having the characteristics (loading and weight per horse-power) of the D.H.50, the relation of the speed to the horse-power becomes a simple one as long as we are only considering a speed of over 100 miles per hour. From about this point upwards, if everything else is equal, the speed will vary in proportion to the cube-root of the horse-power of the engine.

The D.H.50 with the Puma engine giving a maximum of 240 h.p. does 114 miles per hour. If we take the Jaguar horse-power at 410, the speed of the Jaguar machine, if it suffers from no extra resistance, will be

$$114 \times (410/240)^{\frac{1}{3}}$$

—this equals 136 miles per hour.

The measured speed of the D.H.50 J. was 135 miles per hour at a height of 2,000 feet. For ground level it would be almost exactly equal to that shown by the above calculation.

This is certainly an interesting result which we did not quite expect, but nevertheless I do not think this invalidates general conclusions as to the high resistance of radial engines, for the following reason.

The D.H.50 may be taken as an almost ideal case perhaps, since the size of its cabin is such that it just comfortably fairs off the engine.

If we tried to make a really fast aeroplane with a radial engine, the first thing to do would be to cut down the size of the fuselage to a minimum. This then would leave the radial engine sticking out as a disc in front of the fuselage —a thoroughly bad streamline shape, which would give us nothing like the same value for the horse-power. If, on the other hand, we went in the other direction and adapted it to a big cabin machine like the D.H.34, we should probably again be in trouble through having a big fuselage behind a small high-reving propeller. This again would probably give an inferior result; but I should not like to speak with any certainty of the magnitude of this latter loss—it might not be so serious as in the other case.

In multi-engined machines there are, of course, both these cases, the wing engine suffering from the fact that there is not a necessarily incurred piece of resistance like a fuselage which could be used to fair off the engine.

I hope this letter is sufficiently clear, but it has been dictated rather hurriedly as I am just off to Martlesham.

Yours sincerely,

C. C. WALKER.

ON THE PRESSURE DISTRIBUTION ROUND CERTAIN AEROFOILS OF HIGH ASPECT RATIO

BY D. M. WRINCH, D.SC., F.R.A.S., FORMERLY FELLOW OF GIRTON COLLEGE, CAMBRIDGE.

Introduction

The development of aerodynamical research into the usefulness of wing profiles of various types for aerofoils of high aspect ratio lends special interest to new results in two-dimensional hydrodynamics relating to the motion of a perfect fluid in the presence of a cylindrical body, especially in the case when the curve of cross-section of the body possesses only a small amount of camber and is cusped at one end and rounded at the other.

The possibility of formulating a theory which represents with reasonable accuracy the actual motions of aerofoils of high aspect ratio in a stream of air, when the air it taken to be inviscid, depends, of course, essentially in the first place on finding motions in which there is a force on the body at right angles to the direction of streaming. No theory which omits to produce this lifting force can give an account of the actual motions of aerofoils which is even approximately satisfactory.

It is, of course, well known that the streaming of an inviscid fluid past a body gives no resultant force on the body. And the same is true when an inviscid fluid circulates round the body. But when these two motions are combined and the fluid circulates round the body and streams past it, there is a resultant force on the body perpendicular to the direction of streaming at a great distance.* Thus motions in which an inviscid fluid is circulating round a body and streaming past it are of practical importance in aerodynamics since these motions have at least the advantage of providing a resultant lifting force on the body.

In any motion which can be realised in practice we must, however, satisfy a further condition. The relation between the pressure p at any point and the velocity q at that point is given by the formula of Bernoulli

$$p+\tfrac{1}{2}\rho q^2$$

where ρ is the density of the fluid. The particular constant in question in any problem is some finite number determined by the pressure at a great distance. Now with any particular specification of this constant C there is evidently a certain value which the velocity q may not exceed, namely, Q, given by

$$\tfrac{1}{2}\rho Q^2=C$$

for the pressure in the fluid cannot be negative. Thus no motion in which the velocity is unduly large at any point and certainly no motion in which the velocity is infinite at any point has any physical significance. Now it is well known that at a cusp in the curve of cross-section of a body in a fluid there is in general an infinite velocity when the fluid streams past and when the fluid circulates round it. But, when there is circulation round the body as well as streaming past, if the amount of circulation and the velocity of streaming are suitably related, the infinite velocity associated with the cusp disappears. Thus in the case of a cylinder with a cusped edge, simple circulation and simple streaming are of no physical interest, but this particular type of mixed motion, when there is circulation round and streaming past the cylinder in certain proportions, evidently, so far as the resulting pressure in the fluid is concerned, represents a possible type of motion.

It is these two considerations which lend importance even in the face of

* See H. Lamb, *Hydrodynamics*, Cambridge, 1924, pp. 76, 647.

grave difficulties of a fundamental kind* to the solution of certain problems of a fluid circulating round and streaming past a cylindrical body with a trailing edge to which Lanchester† in England and Joukowski‡ on the continent first directed attention; and in this paper we discuss these problems when the curve of cross-section is of various types. In order to discover whether the motions of aerofoils are adequately represented by this type of motion in which streaming and circulation are combined, it is important to compare the data of experiment with the logical consequences of the theory. The data obtained in recent years§ have tended to take the form of the pressure distribution round aerofoils of various sections for angles of incidence ranging from -2° to about 10°, and for this reason we have on this occasion been principally concerned with working out the distribution of pressure predicted by the theory of this special type of mixed motions. It is evidently of importance in a complete survey of the position to derive these pressure distributions for aerofoils of simple symmetric type, and we have in this paper discussed only cases of sections symmetric about an axis. A similar investigation of sections with no axis of symmetry can be developed on the same lines and a comparison of the two investigations would show the effect of symmetry.

A comparison of the general characteristics of these pressure distribution curves with the characteristics of those actually obtained in practice reveals interesting results. These results are not detailed in the present communication, which is intended only to put on record the types of pressure distribution curves obtained in a set of simple sections when the characteristics of small camber, a rounded leading edge and a thin trailing edge found in all the aerofoils so far used, are retained.

The sections here treated have one axis of symmetry, and as usual possess a rounded leading edge and a sharp trailing edge. There is a continuous series of the sections;‖ on this occasion we select for discussion a set of three. Results for the other intermediate types can readily be obtained.

The specifications are as follows:

I.

Ordinate.	Distance from leading edge in terms of chord.	Height above chord in terms of chord.
1	.0000	.0000
2	.0184	.0663
3	.1757	.1132
4	.2750	.1299
5	.3163	.1156
6	.4000	.1000
7	.4898	.0814
8	.6750	.0433
9	.8417	.0150
10	.9581	.0021
11	1.0000	.0000

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* See C. Witoszynski, *La Mechanique des Profils d'Aviation*, Paris, 1922, pp. 14-19; Dictionary of Applied Physics, London, 1923, Vol. V., *Hydrodynamics in its Application to Aeronautics*, pp. 187-188; W. L. Cowley and H. Levy, *Aeronautics in Theory and Experiment*, London, 1920, pp. 64-65; L. Bairstow, *Applied Aerodynamics*, London, 1920, pp. 363-364

† F. W. Lanchester, *Aerodynamics*, London, 1911, ch. iii.

‡ N. Joukowski, *Aérodynamique*, Paris, 1916 (traduit du russe par S. Drzewiecki), ch. vi.

§ See Bairstow, *op. cit.*, Cowley and Levy, *op. cit.*, S. T. G. Andrews and S. F. Benson, *The Theory and Practice of Aeroplane Design*, London, 1920, A. W. Judge, *The Properties of Aerofoils and Aerodynamic Bodies*, London, 1917.

‖ See a paper by the present writer, in which the complete analysis of the hydrodynamical problems associated with cylinders whose cross sections belong to this series are discussed, and all the results used in this paper are obtained.

II.

Ordinate.	Distance from leading edge in terms of chord.	Height above chord in terms of chord.
1	.0000	.0000
2	.0272	.0166
3	.1067	.0284
4	.2312	.0325
5	.3889	.0289
6	.4750	.0250
7	.5626	.0211
8	.7312	.0108
9	.8727	.0038
10	.9669	.0005
11	1.0000	.0000

III.

Ordinate.	Distance from leading edge in terms of chord.	Height above chord in terms of chord.
1	.0000	.0000
2	.0287	.0083
3	.1118	.0142
4	.2406	.0162
5	.4010	.0144
6	.4875	.0125
7	.5737	.0105
8	.7406	.0054
9	.8778	.0019
10	.9684	.0003
11	1.0000	.0000

We give in the following table the camber of the sections and the distance of the maximum ordinate from the leading edge. It is also useful to put on record the centre of gravity coefficient, viz., the distance of the centre of gravity from the leading edge in terms of the chord.

Aerofoil. No.	Camber of upper and lower surface.	Distance of Max. Ordinate from leading edge in terms of chord.	Centre of Gravity Coefficient.
1	.130	.175	.3389
2	.0325	.231	.3658
3	.0162	.241	.3698

AEROFOIL. Nº 1.

AEROFOIL Nº 2.

AEROFOIL Nº 3.

A right cylinder whose cross-section is one of the series of curves under discussion in this paper is immersed in a fluid filling the external space up to a rigid boundary at a distance very large compared with the dimensions of the curve of cross-section. We consider the motion in the layer between the transverse sections of the cylinder at unit distance apart. By the symmetry of the situation the whole problem is reduced to a problem in two dimensions; the motion in any one transverse plane is the same as the motion in any other transverse plane section, provided that the planes in question are not too near the ends of the cylinder.

The fluid is taken to be streaming in a direction making an angle β with the chord of the wing sections, with velocity U. The lines of flow of the fluid streaming past the wing section can be mapped. On this motion we superpose a circulatory motion k round the cylinder in the clockwise direction. Now circulation round a cylinder together with flow past a cylinder can be shown to produce a force at right angles to the line of flow at a distance. This force called the Lift is in fact given by

$$\text{Lift} = \text{Density} \times \text{Velocity} \times \text{Circulation}$$

or

$$L = \rho U k$$

Now, in general, this motion involves an infinite velocity at the sharp trailing edge. The pressure p at any point is given in terms of the velocity q at that point and the pressure at a great distance p_0 by the formula

$$p = p_0 - \tfrac{1}{2} \rho U^2 (q^2/U^2 - 1).$$

If, therefore, the velocity is at any point too big, the pressure may become negative. This is a physical impossibility and may be interpreted to mean that the motion under discussion is not a possible one from the physical standpoint. This is evidently the case if the velocity at any point is infinite, for then with no finite value whatever of the pressure at infinity p_0 can we avoid getting a negative pressure at that point.

Nevertheless, it has been shown by Joukowski* in the case of certain wing sections that a combination of streaming past and circulation round a cylinder in certain proportions yields a motion in which the velocity is never infinite. In the case also of the wing sections treated in this paper, such a composite motion is possible.† We need, in fact, for any specific angle of streaming β to have the special ratios of circulation k to (velocity of streaming × chord) given in the following table:

Aerofoil No.	$k/(U \times \text{chord})$
1	$3.770 \times \sin \beta$
2	$3.299 \times \sin \beta$
3	$3.212 \times \sin \beta$

The distribution of pressure over the aerofoil is of great practical importance. This is shown in the figures for angles of incidence 0°, 5° and 10° in the case of each of the three aerofoils. Since the change of pressure is given by

$$p_0 - p = \tfrac{1}{2} \rho U^2 (q^2/U^2 - 1)$$

we plot $(q^2/U^2 - 1)$ after the usual manner as a numerical coefficient of change of pressure. We append tables giving the values of q^2/U^2 in the various cases.

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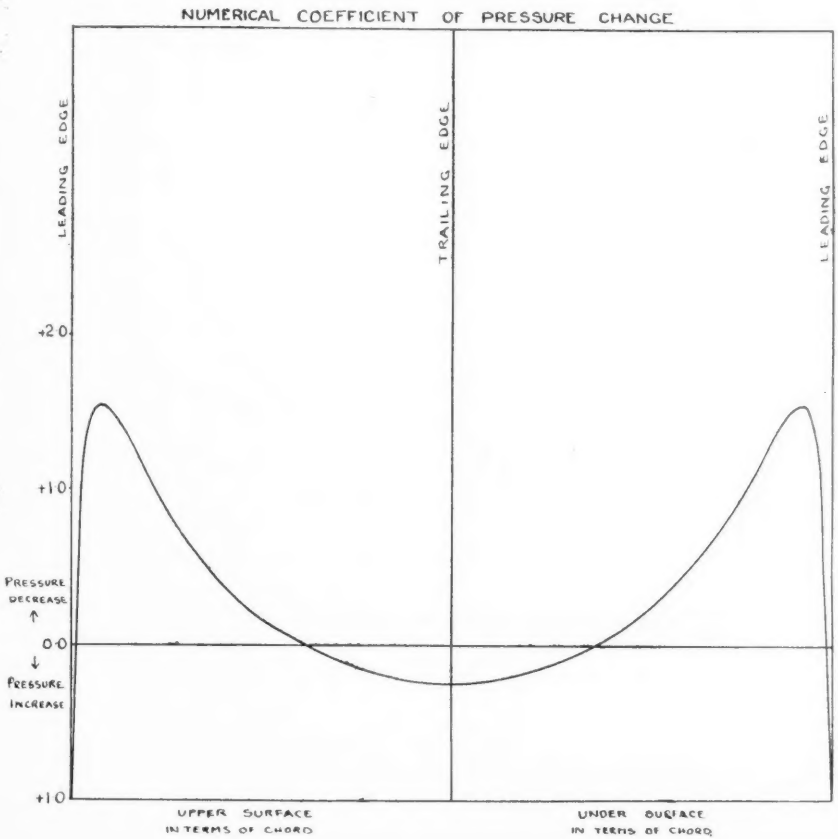
* *loc. cit.*; see also A. R. Low, *The Circulation Theory of Lift*, International Air Congress, London, 1923.

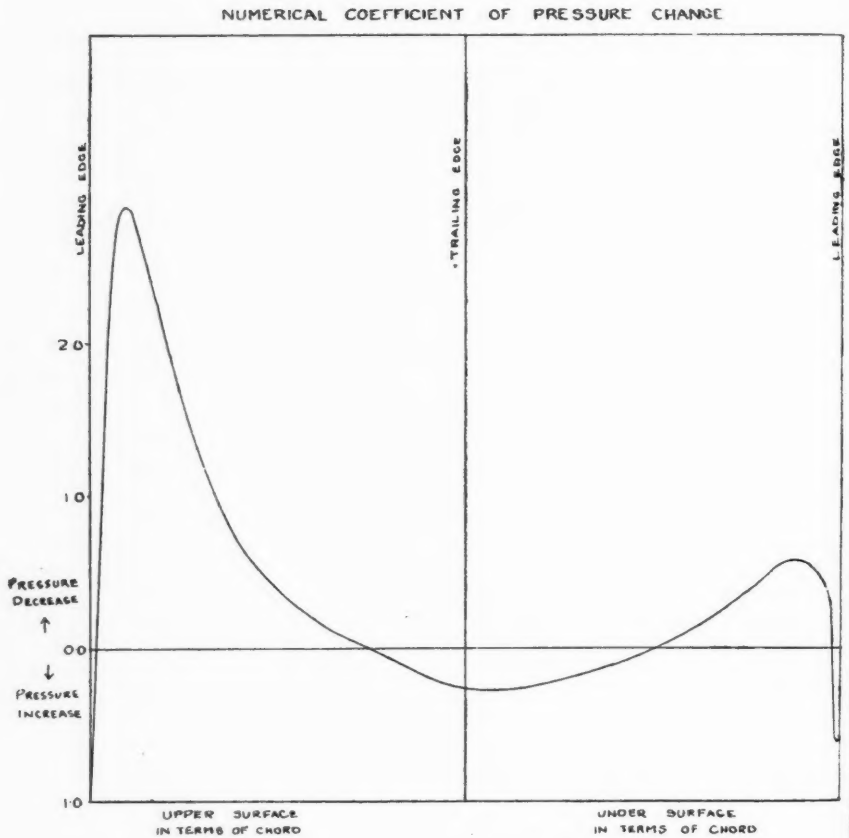
† See the paper by the present writer, *loc. cit.*

TABLE OF q^2/U^2 FOR AEROFOIL NO. 1.

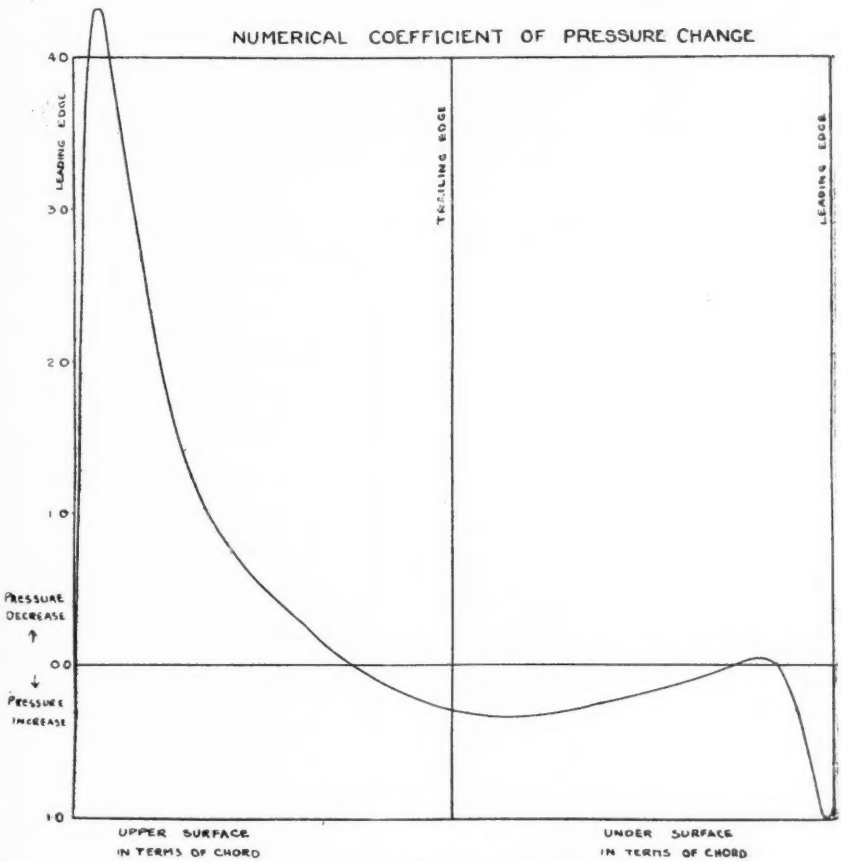
Point of Aerofoil.	Distance from leading edge in terms of chord.	0°	5° lower side.	5° upper side.	10° lower side.	10° upper side.
1	.0000	.0000	.2735		1.0856	
2	.0184	1.0400	2.3156	.2620	4.0340	.0000
3	.0757	2.5410	3.8802	1.4550	5.4310	.6541
4	.1750	2.1988	2.9609	1.6075	3.7184	1.0528
5	.3163	1.6054	1.9428	1.2783	2.2853	.9714
6	.4000	1.3847	1.6250	1.1442	1.8582	.9111
7	.4898	1.2129	1.3870	1.0335	1.5496	.8450
8	.6750	.9644	1.0562	.8628	1.1354	.7545
9	.8417	.8277	.8745	.7700	.9091	.7030
10	.9581	.7566	.7742	.7280	.7901	.6889
11	1.0000	.7347	.7291		.7125	



AEROFOIL N°1 ANGLE OF INCIDENCE 0°



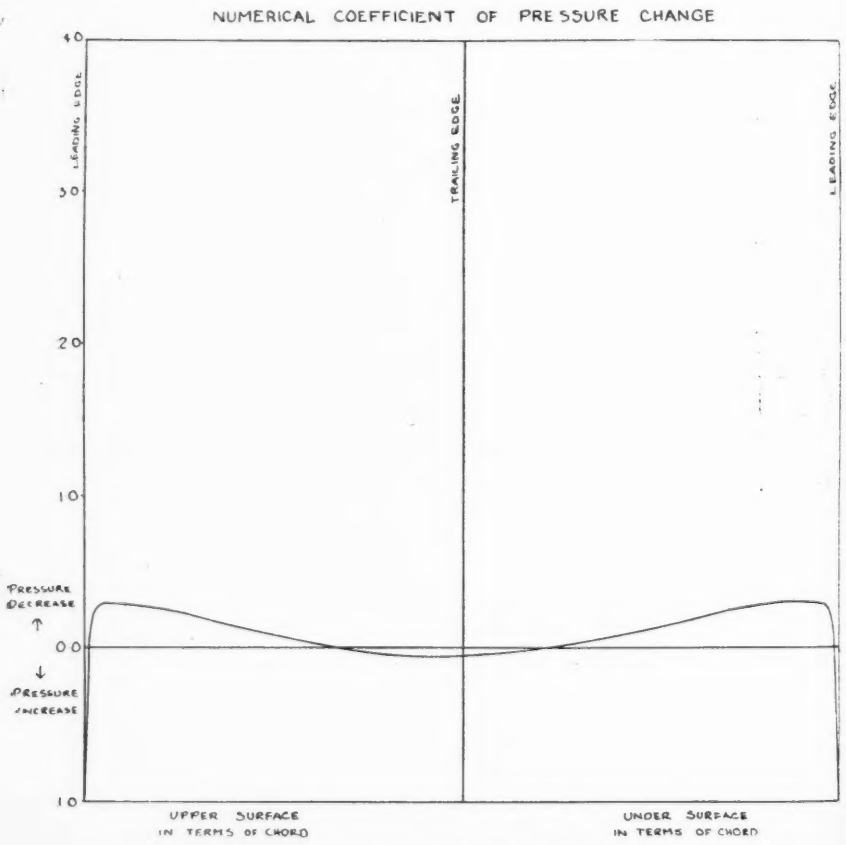
AEROFOIL N°1 ANGLE OF INCIDENCE 5°

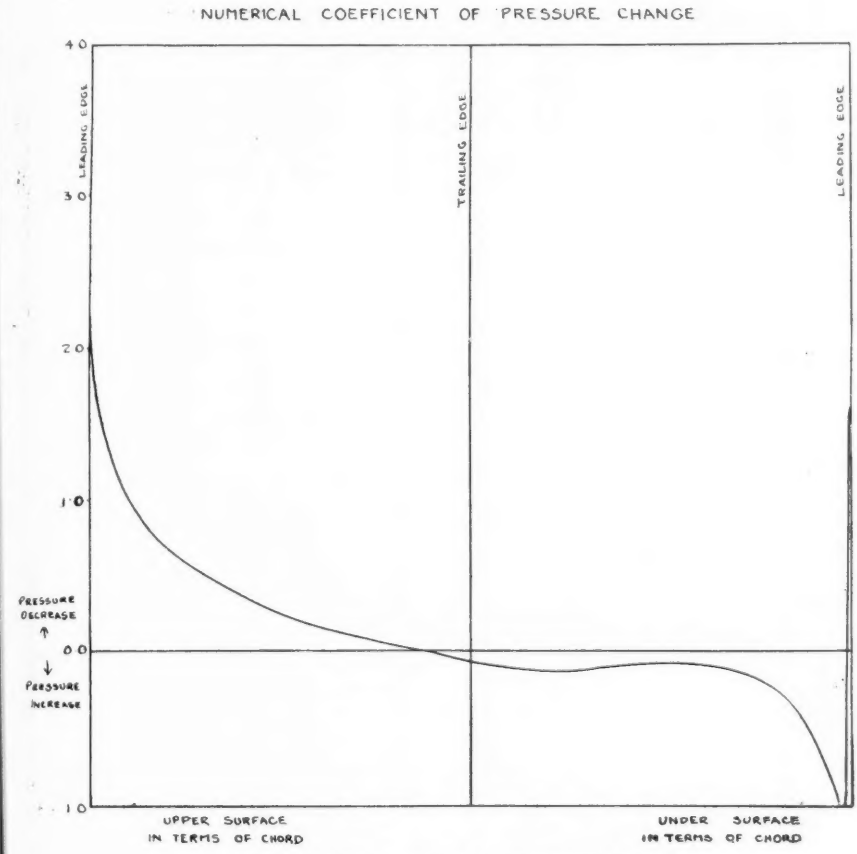


AEROFOIL N° 1 ANGLE OF INCIDENCE 10°

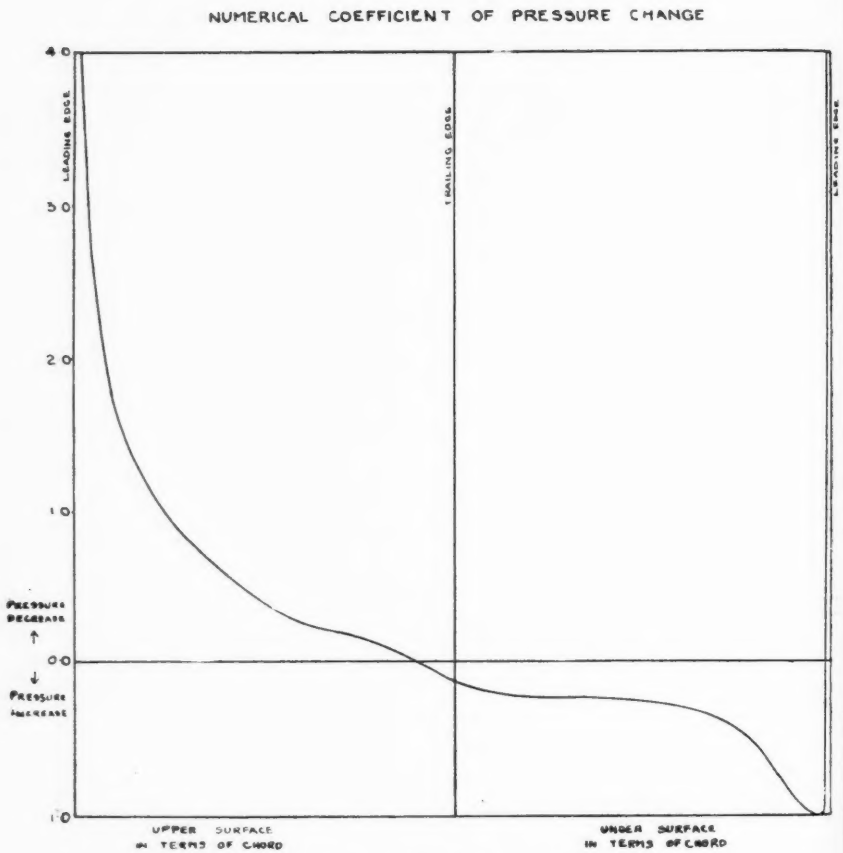
TABLE OF q^2/U^2 FOR AEROFOIL NO. 2.

Point of Aerofoil.	Distance from leading edge in terms of chord.	0°	5°		10°	
			lower side.	upper side.	lower side.	upper side.
1	.0000	.0000	3.3500		13.30	
2	.0272	1.2490	2.7747	.3146	4.8452	.0000
3	.1067	1.2734	1.9442	.7292	2.7214	.0382
4	.2312	1.2215	1.6071	.8727	2.0190	.5916
5	.3889	1.1392	1.3768	.9071	1.6179	.6893
6	.4750	1.1000	1.2908	.9089	1.4759	.7237
7	.5626	1.0638	1.2164	.9064	1.3597	.7490
8	.7312	.9970	1.0919	.8910	1.1738	.7801
9	.8727	.9491	1.0028	.8829	1.0474	.8061
10	.9669	.9211	.9468	.8660	.9006	.8387
11	1.0000	.9119	.9084		.8825	





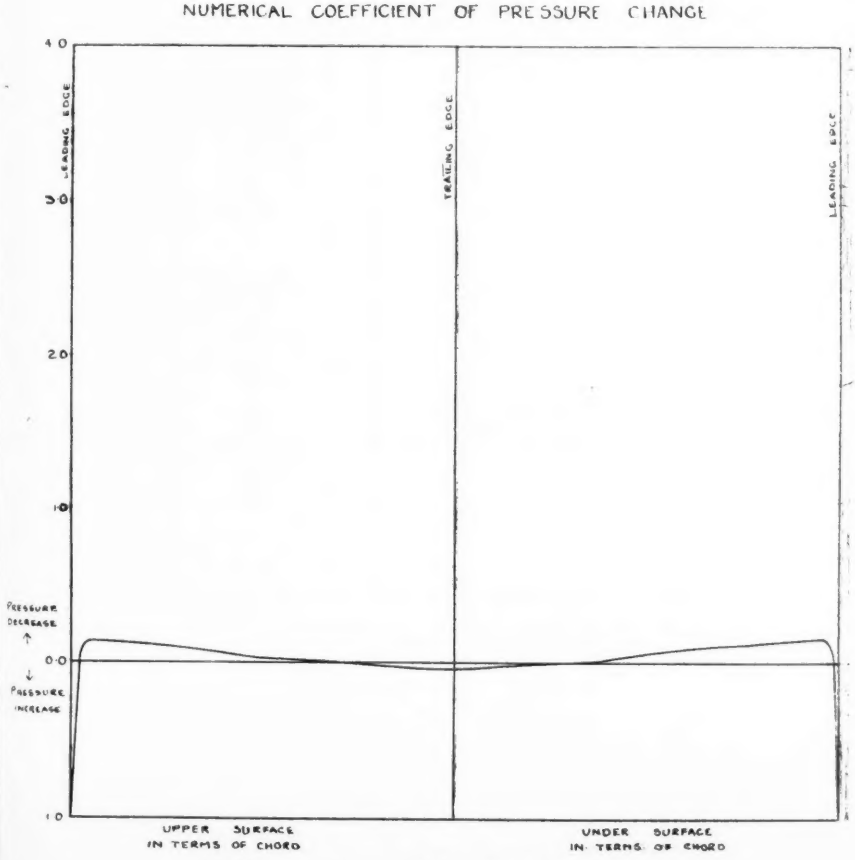
AEROFOIL N° 2 ANGLE OF INCIDENCE 5°

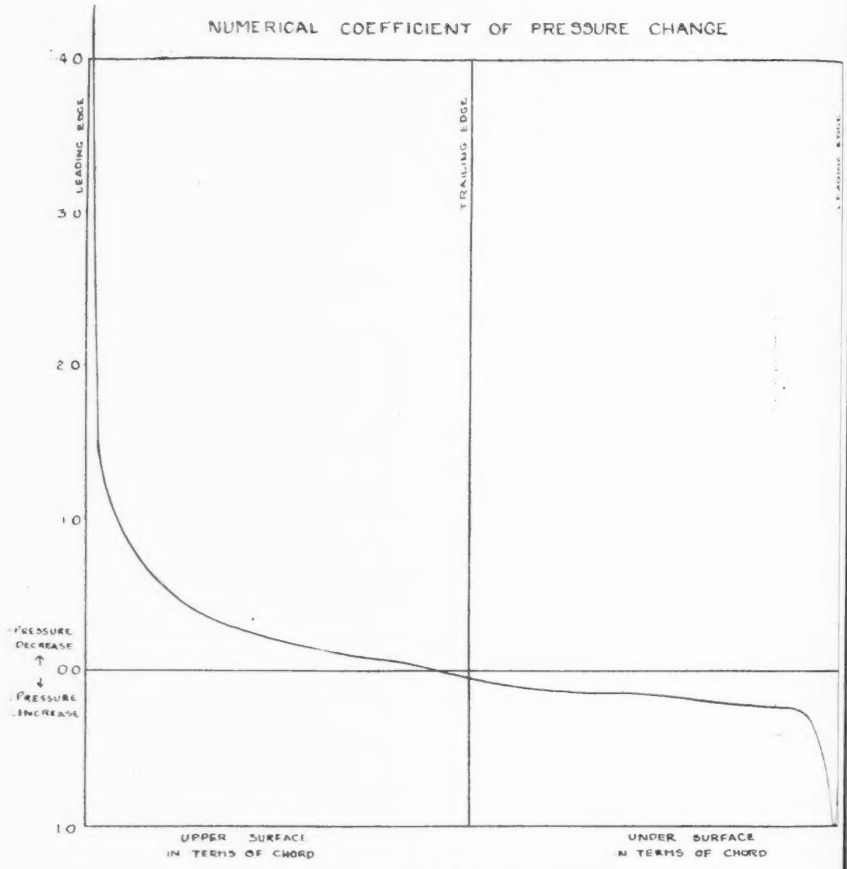


AEROFOIL N° 2. ANGLE OF INCIDENCE 10°

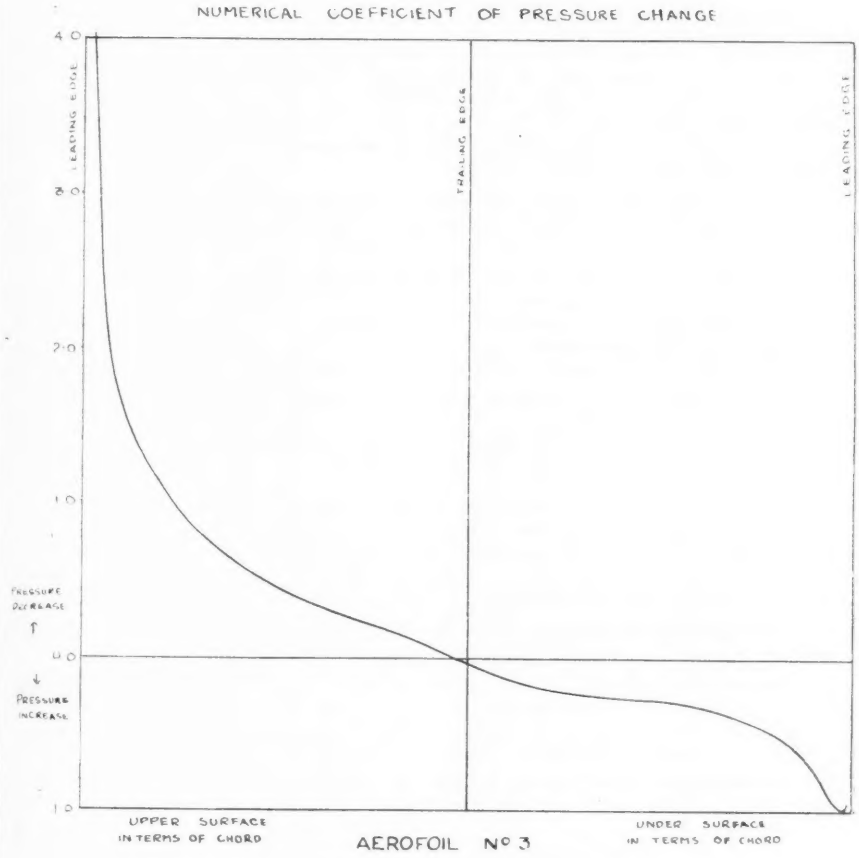
TABLE OF q^2/U^2 FOR AEROFOIL NO. 3.

Point of Aerofoil.	Distance from leading edge in terms of chord.	0°	5° lower side.	5° upper side.	10° lower side.	10° upper side.
1	.0000	.0000	12.887		51.168	
2	.0287	1.1427	2.5385	.2287	4.4328	.0000
3	.1118	1.1394	1.7398	.6526	2.4352	.2937
4	.2406	1.1086	1.4588	.7934	1.8323	.5188
5	.4010	1.0715	1.2966	.8512	1.5217	.6483
6	.4875	1.0546	1.2379	.8717	1.4485	.6940
7	.5737	1.0355	1.1841	.8824	1.3236	.7292
8	.7406	1.0018	1.0997	.8983	—	.7856
9	.8778	.9786	1.0340	.9103	1.0749	.8311
10	.9684	.9632	.9902	.9266	—	.8770
11	1.0000	.9529	.9500		.9242	





AEROFOIL No 3 ANGLE OF INCIDENCE 5°



AEROFOIL No 3

ANGLE OF INCIDENCE 10°

INFORMAL DISCUSSION

Engine Starters

An informal discussion was held on December 17th, 1925, in the Library of the Society, on various Aero Engine Starting Systems.

Wing Commander HYNES opened the discussion by outlining, as follows, what he considered to be the requirements which a good engine starting system should fulfil. It must be light. Quick and reliable in action. It must be capable of starting the engine when in any position. It must be operated by one man and, preferably, by the pilot when sitting in his seat. It should require no special stores, fuel, etc. It must be cheap. There should be no limit to the number of starts which it can give. He described the R.A.E. gas starter system and its application to various engines.

Mr. FEDDEN sent a letter describing the application of the Bristol starter to air-cooled radials, and also the application of the Aero-Marine fly-wheel starter.

The Aero-Marine fly-wheel starter was also described by Colonel ORME. In this system, a starting handle is used, through gearing, to spin a 5in. diameter 5lb. fly-wheel to extremely high speed. A clutch is then engaged and the energy in the fly-wheel is sufficient to turn the main engine at the same speed to which the starting handle had been worked up. Very satisfactory results have been obtained in America with this system when applied to a Liberty engine.

Mr. WILKINSON described the hand starting gear of the Napier engines.

Mr. MANNING advocated the use of a very small petrol engine to turn the main engine through any satisfactory form of gearing, similar to that employed in hand starting.

Some details were given of the C.A.V. system of electric starting and the B.T.H. impulse starter in the magneto drive was also described. This latter fitting causes the magneto to move with a sudden jerk at the right part of the stroke, so that a strong spark is given at the right time, although the engine may be turning very slowly indeed.

There was then a general discussion which brought out many interesting points, although it was not intended to reach a general conclusion.

Considerable preference was expressed for the small auxiliary engine, turning the main engine at sufficient speed to start it. Such a system appeared probably simpler and lighter than a gas starter when coupled to a single engine, but had not the advantage of the latter system when applied to a multi-engined aeroplane.

Attention was drawn to the necessity of very satisfactory and reliable arrangements for starting the small engine in either system.

Electric starters were considerably criticised not only on account of the weight of their batteries, but by reason of the danger of fire, consequent upon the short circuit of batteries capable of such high current discharge.

Attention was drawn to the failure of gas starters when one valve of the main engine is sufficiently sticky to remain slightly open and prevent the accumulation of pressure necessary to turn the engine. Such a defect may well exist in a cold engine and prevent its starting, although when once the engine was started and warm the defect would probably remedy itself.

Some fifty people were present, of whom about twenty spoke, several more than once.

RESUMÉ OF TECHNICAL INFORMATION

OCTOBER—NOVEMBER, 1925

Compiled by the Directorate of Technical Development (R.T.P.), Adastral House, Kingsway, London, W.C.2

AIRSHIPS

U.S.A.

Inertia Factors of Ellipsoids for Use in Airship Designs. N.A.C.A. Report No. 210. (11125.)

This report is based on a study made by L. B. Tuckerman as a member of the Special Committee on Design of Army Semi-rigid Airship RS-1, appointed by the National Advisory Committee for Aeronautics.

The increasing interest in airships has made the problem of the potential flow of a fluid about an ellipsoid of considerable practical importance. In 1833 George Green, in discussing the effect of the surrounding medium upon the period of a pendulum, derived three elliptic integrals, in terms of which practically all the characteristics of this type of motion can be expressed. The theory of this type of motion is very fully given by Horace Lamb in his "Hydrodynamics," and applications to the theory of airships by many other writers. Tables of inertia coefficients derived from these integrals are available for the most important special cases. These tables are adequate for most purposes, but occasionally it is desirable to know the values of these integrals in other cases where tabulated values are not available. For this reason it seemed worth while to assemble a collection of formulæ which would enable them to be computed directly from standard tables of elliptic integrals, circular and hyperbolic functions, and logarithms without the need of intermediate transformations. Some of the formulæ for special cases (elliptic cylinder, prolate spheroid, oblate spheroid, etc.) have been published before, but the general forms and some special cases have not been found in previous publications.

Report No. 210 may be obtained upon request from the N.A.C.A., Washington, D.C.

Stability Equations for Airship Hulls. N.A.C.A. Report No. 212. (21125.)

This report is by A. F. Zahm. In the text are derived simple formulæ for determining directly, from the data of wind-tunnel tests of a model of an airship hull, what shall be the approximate character of oscillation, in pitch or yaw, of the full-scale ship when slightly disturbed from steady forward motion.

AIRCRAFT

France

Pierre Carmier Touring Biplane. Les Ailes. 8.10.25. (31125.)

The fuselage and the wings of this aircraft are entirely covered with plywood. The wings, which have a very heavy stagger, are mounted on the fuselage, which has a roomy cockpit for pilot and passenger. This fuselage really constitutes a wing profile, and is a very interesting feature of the aircraft.

The engine installed is a three-cylindered 40 h.p. Anzani, of 4,000 c.c. capacity.

The aircraft has carried out more than twelve hours' flight, and developed a speed of 80 m.p.h. The minimum speed is 28 m.p.h., the total weight loaded is 992 lbs., and the useful load 441 lbs.

Trials of 1,600 h.p. Four-Engined Latham Seaplane *L'Aeronautique*—*No.* 76, *September*, 1925. (41125.)

This seaplane, which has been constructed for the French Navy, has recently carried out its acceptance tests.

The aircraft, which carried a load of 6,944 lbs., took off in seventeen seconds, and climbed to 6,560ft. in 21 minutes. It finally reached a height of 10,830ft., and the speed attained was 99 m.p.h. The aircraft alighted on the water without difficulty.

The chief characteristics of the seaplane are:—

Span, 110ft.
Height, 23ft.
Length, 68ft. 3ins.
Wing loading, 8.9 lb. sq. ft.
Engine loading, 15.2 lb. h.p.

Italy

New Caproni Armoured Biplane for Ground Straffing, Type 70. *L'Air, No.* 142. 1.10.25. (51125.)

This new biplane is intended for co-operation with the infantry at low altitudes. It can also be used as a night fighter, as it has a very good field of vision.

The aircraft is armoured with Poldi steel, and carries four machine-guns and a camera.

The engine installed is a 400 h.p. Bristol Jupiter.

The following are the chief characteristics:—

Span of top wing, 45ft. 11ins.
Span of bottom wing, 26ft. 3ins.
Wing chord, 8ft. 2ins.
Wing area, 593 sq. ft.
Weight empty, 2,888 lbs.
Useful load, 1,808 lbs.
Total loaded weight, 4,996 lbs.
Maximum horizontal speed, 124 m.p.h.
Minimum speed, 56 m.p.h.
Factor of safety, 10.

Roumania

The Stoika Flying Boat. *Les Ailes.* 1.10.25. (61125.)

This aircraft is a sesquiplane, fitted with a 220 h.p. Hiere engine. It was designed by a Roumanian engineer, and has been built, in two and a half months entirely of Roumanian material.

The characteristics are as follows:—

Span, 52ft.
Length, 34ft.
Weight, 3,968 lbs.
Speed, 99 m.p.h.
Ceiling, 13,120ft.
Endurance, eight flying hours.

Power Units

U.S.A.

The Effect of Changes in Compression Ratio upon Engine Performance. N.A.C.A. Report No. 205. (71125.)

This report, by Stanwood W. Sparrow, is based upon engine tests made at the Bureau of Standards during 1920, 1921, 1922 and 1923, and has been prepared for publication by the National Advisory Committee for Aeronautics. The majority of these tests were of aviation engines and were made in the altitude laboratory. For a small portion of the work a single-cylinder experimental engine was used. This, however, was operated only at sea-level pressures.

The report shows that an increase in brake horse-power and a decrease in the pounds of fuel used per brake horse-power hour usually results from an increase in compression ratio. This holds true at least up to the highest ratio investigated, 14 to 1, provided there is no serious preignition or detonation at any ratio. To avoid preignition and detonation when employing high compression ratios it is often necessary to use some fuel other than gasoline. It has been found that the consumption of some of these fuels in pounds per brake horse-power hour is so much greater than the consumption of gasoline that it offsets the decrease derived from the use of the high compression ratio. The changes in indicated thermal efficiency with changes in compression ratio are in close agreement with what would be anticipated from a consideration of the air cycle efficiencies at the various ratios. In so far as these tests are concerned, there is no evidence that a change in compression ratio produces an appreciable consistent change in friction horse-power, volumetric efficiency, or in the range of fuel-air ratios over which the engine can operate. The ratio between the heat loss to the jacket water and the heat converted into brake horse-power or indicated horse-power decreased with increase in compression ratio.

A copy of Report No. 205 may be obtained upon request from the National Advisory Committee for Aeronautics, Washington, D.C.

Miscellaneous

France

New Method of Welding Aluminium Bronze. Les Ailes. 24.9.25. (81125.)

A chemical powder, which permits of very thin aluminium bronze being welded perfectly, has been invented by M. R. Vincent.

Utilising this method, a test tank was constructed of cupro-aluminium, with a capacity of 96 gallons, having internal partitions, filling cock, connection for the level gauge, filter and emptying cock. This tank, which weighed 44.5 lbs., withstood a watertightness test under a pressure of 1.8 lb., whereas a duralumin tank of the same capacity was not able to withstand a test under a pressure of .5 lb.

With regard to the welding, micrographic examination and tensile tests on test-pieces of sheet metal, 4/10 m.m. thick, showed that it had not affected the metal in any way.

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"The Cierva Autogire."

REVIEWS

The Strength of Materials

A Treatise on the Theory of Stress Calculations for Engineers. By JOHN CASE, M.A., F.R.Ae.S. Pp. viii+558. 30/- net. 1925. (Arnold.)

Mr. Case gives a solid account both of the first notions of the subject, and of the harder problems that have been solved hitherto. Besides the usual matter, a great deal is brought together from British and foreign periodicals, and we are grateful to the author for his labour in collecting and supplementing them.

The explanations of stress and strain are clearer than in most text-books; that of shear, illustrated by a chapter on rivets, is particularly good. Besides the simpler cases of struts and beams, there are included discussions of curved members, irregular sections, springs, shells and plates, and much important work on torsion. A short chapter on oscillations, with no reference to any larger work, and one on fatigue, are too sketchy and detached to be of much use; an expansion of these might well take the place of some elaborate details of calculus, such as the familiar transformation of Laplace's operator from Cartesian to polar co-ordination.

Much discretion is shown in the choice of results, both theoretical and numerical, to be discussed in full, summarised, or merely given among the examples, of which there is a large collection. The frankness about our ignorance on strut failure and such matters is perhaps overdone, in view of the elaborate theories which follow.

It is a pity that the aim of the book is avowed to be no higher than to enable an honours candidate to begin and "complete" his studies, and also that so much good work is obscured by careless style and detail. A mathematician has no business to add to the prevailing confusion between maximum and greatest value, or between a junction and its gradient. The argument on p. 95 is false; *all* the theories there compared give continuous values of the stress. The reader is continually jarred by phrases such as "the exact expression is . . . very nearly"; "an unbalanced thrust . . . is balanced by. . . ." The get-up, printing and index are good, but the diagrams are neither clear nor accurate.

In spite of petty defects, the book is a mine of information as to what stress problems have been solved, and by what methods. Any student can learn a great deal from it, and a research worker will find its full references invaluable.

H. P. HUDSON.

The German Air-Raids on Great Britain, 1914-1918

By Captain JOSEPH MORRIS. (Sampson Low. 16/-.)

The publishers are greatly to be congratulated on producing this handsome book of 305 pages, with many illustrations and no less than six folding maps, at the extremely moderate price of 16/-. It is a very notable piece of enterprise, for which they deserve our warm thanks.

Except for a series of articles in the *Times* some years ago, no detailed history of the German air-raids on this country during the war has been published, and, since all details were censored at the time, it has been exceedingly difficult to be sure of the facts, as memory is notoriously fickle, and few concerned had the time or opportunity for diary writing. No doubt some day the gap will be filled when the second and subsequent volumes of the official history appear—though when this will be is problematical in view of the fact that up to the present the Air Council have neglected to appoint a successor to the late Sir Walter Raleigh. Captain Morris's book is therefore welcome, as providing a much needed record, and contains at the end invaluable data in the form of lists of the raids carried out and of the airships brought down. We think he might have added still further to the value of these records if he had incorporated in the former a list of the

airships taking part in each raid. It is true that this information is available in the text, but in a less convenient form for reference. The remarkable war record of L.11, L13, and L.14, for instance do not appear, though they are certainly worthy of record. L.11 first appeared over England on June 15th, 1915, and continued to take part in raids until September 3rd, 1916, while L.13 and L.14 both made their first raid on August 9th, 1915, and their last on November 27th, 1916, the last-named being credited with participation in no less than 24 raids. All three of these airships continued to be used for training after their active raiding had ceased, and L.14, at least, was still in existence when the Commission of Control visited Nordholz in 1919. This very remarkable record is not commonly known, and provides a salutary lesson for those who affect to despise the airship for military purposes.

Captain Morris has written his book in the form of a detailed story of the movements of the aircraft concerned in each raid, and individual accounts of the flights of the various British pilots sent up to combat them. This procedure provides a great deal of interesting and valuable information, but it has resulted in a certain lack of balance. No attempt has been made to give any picture of the co-ordination which was finally arrived at between the various methods of defence—guns, searchlights, balloon aprons, and aeroplanes. A disproportionate importance is therefore given to the feats of aeroplane pilots, and the book becomes largely valueless to the serious student of anti-aircraft defence. There is also a slight tendency to belittle the courage and resource of the raiders, who were, after all, whether in airship or aeroplane, very gallant men engaged upon a perfectly legitimate war operation—in spite of our somewhat hypocritical contemporary propaganda to the contrary. In one instance, Captain Morris does less than justice to the Zeppelin designers. At the beginning of Chapter XIV., though it has strictly no connection with the subject of his book, he refers somewhat contemptuously to "L.57, which had been specially built to carry ammunition and medical stores to the hard-pressed German troops in East Africa, but which never got there. She perished by fire on a trial flight on October 7th, 1917." Having said so much, he should have referred to L.59, L.57's sister ship, of 2,240,000 cubic feet capacity, which sailed from Jamboli in Bulgaria for German East Africa, with the stores concerned weighing 20 tons, at 8 a.m. on November 21st, 1917, and got considerably beyond Khartoum before being recalled by wireless owing to the surrender of the German forces she was to relieve. She landed again at Jamboli at 8 a.m. on November 25th, after exactly 96 hours in the air, and a flight which stood alone in airship annals until R.34's double crossing of the Atlantic in 1919.

"*My Polar Flight.*"

Roald Amundsen.

Amundsen is an idealist, but an idealist with the determination and organising ability to achieve his ideals and, moreover, a great leader of men. So much is clear on a reading of this book, even to one who might have forgotten that he is dealing with the conqueror of the South Pole.

The most daring and the greatest of flights, judged by the human factor, since Alcock and Brown set their course eastwards from Newfoundland, cannot fail to arouse the interest, not only of aeronautical circles, but of the public, too. This was no scratch affair, this flight, except in so far as every man who ever organised an expedition yet has had to scratch very hard for every penny of the money which it cost. Amundsen had had this flight in mind for many years and had been definitely engaged in the organisation of it since 1922. At least three machines were crashed during reconnaissance work before the N.24 and N.25 (numbers which are destined to retain the peculiar significance of such as N.C.3 and R.34) came upon the scene in 1925, through the gift of the American, Ellsworth.

No one needs reminding that the machines selected were Dornier Wals with two Rolls-Royce Eagle engines in tandem. The choice both as to machine and engine was justified. No one probably doubted that the choice of engine was justified, but on the other hand, no one can have foreseen the amazing performance of the duralumin hulls of the boats, when landed on floating blocks of ice and subjected to the pressure of the screwing ice. N.25 hull was scarcely damaged. It is perhaps one of the chief defects of the book that no photographs are included of the landing place or its surroundings at 87°, 43′ N., except one small chunk of ice with the Norwegian flag atop. One has a justifiable curiosity with regard to the landing and the subsequent attempts to take off, but one must conjure up what picture one can from the verbal description.

As to the book itself, it is a literary meal served in several courses, and as often happens, some of the courses are less satisfying than others. Amundsen provides the first with an account of the expedition, and there are several places where one would wish for something more solid. One wants to know why the rear engine of N.25 cut out. There is no mention of it after the landing. One wants to know precisely how N.25 was got up on to the ice. We know that the engines were used, but Amundsen does not say so. We want to know how five weakened men could lift on their shoulders a weight of 4½ tons; and some of the feats of cutting through ice seem to those who have had experience of this work almost Brobdignagian.

However, whatever the qualities of the description, one can have nothing but admiration for the amazing feats of endurance and perseverance which these six men must have accomplished. Amundsen's insufficient acquaintance with the English language no doubt accounts for a certain unsatisfied feeling.

Riiser Larsen has a better command of English, but it is not equal to his well-known skill as a pilot and wide technical knowledge of aeronautics. In fact, when it comes to a technical matter, it leads him into passages like this:—

"The sun would then be over that meridian, the latitudinal difference of which from Greenwich is equal to the time taken for a clock to strike, according to G.T.T. and would be in its zenith over the point, the breadth of which is equal to the sun's declination."

This means, "The sun would then be on that meridian whose longitude in time is equal to G.A.T. and would be in the zenith at a point whose latitude is equal to the sun's declination."

One quotes this because one feels that the publishers had a certain responsibility in seeing that an important book of this kind was properly prepared. There seems to have been too much hurry to put it on the market. We are told in the book that this was due to pressure from the publishers. It would have been very easy to ensure that technical matters were put into good technical English.

Riiser Larsen's chapter will be found the most interesting from the technical point of view. Sverdrup's method of navigation, which is a modified meridian altitude method, is difficult to understand on account of the wording. The sun-compass and the Behm echo sounder alone make the book worth reading.

Chapters are contributed by Dietrichson, the pilot of N.24; Fredrik Ramm, the Norwegian Press correspondent on the *Fram*; Dr. Bjerknes, the head of the Norwegian meteorological service, whose studies of Polar weather are world-famed; and finally by Ellsworth, the navigator of N.24.

Throughout the book one is impressed by the luck which only comes to those who dare greatly. For example, the ice in King's Bay, without which it would have been impossible to get off, broke up a few days after the start; N.24 and N.25 drifted together after the landing and not apart; the controls of N.25, which had been giving trouble throughout the return flight, did not completely jamb until within a mile of North Cape.

For all its defects, a book to read!